

INTERN EXPERIENCE AT  
ROCKWELL INTERNATIONAL

An Internship Report  
by  
THOMAS JAMES TALLEY

Submitted to the College of Engineering  
of Texas A&M University  
in partial fulfillment of the requirements for the degree of  
DOCTOR OF ENGINEERING

December 1982

Major Subject: Electrical Engineering

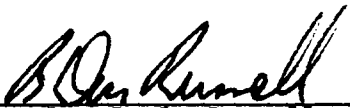
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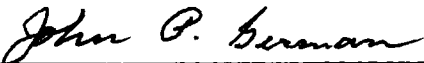
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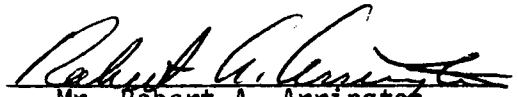
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December 1982

## ABSTRACT

Internship Report (Record of Study)  
Covering a 9-month Doctor of Engineering Internship at  
Rockwell International, UCS (May 1979 - January 1980)  
Thomas James Talley, B.S., Texas A&M University 1971  
M.S., Texas A&M University 1979

A description of an internship experience at Rockwell International Utility Communications System (UCS) is presented. Mr. Talley's work as a systems engineer in the Research and Development Department of the Rockwell International UCS Venture is reviewed. This report is submitted in order to document the experience and indicate how it fulfills the requirements for a Doctor of Engineering Internship.

The assignments which were accomplished during the internship period required involvement in all areas of the UCS business. Detailed engineering, system design, marketing, budgeting, report writing, product testing, and customer relations were all performed at various times during the internship period and are reviewed herein.

## ACKNOWLEDGEMENTS

To Linda, John Paul, and Jo Ann, who endured more than anyone should be asked to endure to allow me to finish this effort.

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## INTRODUCTION

This report documents the internship experience which I had at Rockwell International. The objectives of the internship as stated by Section VI, of the STUDENT MANUAL DOCTOR OF ENGINEERING PROGRAM, and letter to Prospective Engineering Graduate Students, April 1979 are as follows:

- 1 To enable the student to demonstrate his ability to apply his knowledge and technical training by making an identifiable contribution in an area of practical concern to the organization or industry in which the internship is served, and
- 2 To enable the student to function in a non-academic environment in a position where he will become aware of the organizational approach to problems in addition to traditional engineering design or analysis.

These may include, but are not limited to, problems of management, labor relations, public relations, environmental protection, and economics, for example, Section VI, of the letter/student manual further stipulates what information the report should include. An outline of the required data is shown below and was used as a general guide for structuring the internship report.

- 1 Objectives of the job assignment(s) during the internship.
- 2 Intern's position with the organization.
  - a) The technical nature of the job.
  - b) Administrative duties.
- 3 Names of the immediate supervisors, their titles during the time covered by the internship and the name of the intern supervisor if different from the immediate supervisor.
- 4 Details of a specific assignment which would include:
  - a) Objective of the assignment.
  - b) The task description.
  - c) Administrative assignments.



- d) Describe the non-technical problems associated with the specific assignment that could include such items as management, labor relations, public relations, environmental protection and economics.
- e) Method or approach to task.
- f) Sources of information required to perform task.
- g) Discussion of information pertinent to task, which was not readily available (i.e., estimates, approximations or guesses which were made, the significance and limitations of such estimates, the desirability or necessity for further work or research to obtain needed information or data, etc.).
- h) Consequences (e.g., what was the most valuable thing learned from the experience; what were the limitations in knowledge or resources which might restrict the usefulness or full implementation of results; in what area could the internship have been improved).
- i) Contributions to any area outside of the direct assignment. These may include suggested ideas and improvements as well as measurable accomplishments.

I chose these topics for many of the section headings of this report. I chose them in this fashion to assist the evaluators of this report in their efforts to determine if the report meets the above requirements. Other topics were added for completeness.

## ROCKWELL INTERNATIONAL

Rockwell International is a large, multinational organization. Probably best known as prime contractor on the space shuttle, Rockwell is a highly diversified company which is also involved in axle and valve manufacturing. Rockwell was organized in 1928 and chartered as a Delaware corporation. It is engaged in research and development, as well as manufacture and sale of many products for commercial and government markets. In fiscal year 1980, the year which this report covers, 37% of the company's total sales were made to or under U.S. Government contracts or subcontracts (Rockwell International Form 10K, 1980).

### General Organization

Rockwell's operations are conducted in four major business areas.

- 1 Automotive businesses develop, manufacture and market various components for heavy-duty trucks, special purpose vehicles, light trucks and passenger cars.
- 2 Aerospace businesses do research and development and manufacture of space systems and rocket engines, and military and general aviation aircraft.
- 3 Electronics businesses are engaged in research and development and manufacture and marketing of a broad range of guidance and control, avionics, telecommunications and microelectronics systems and equipment.
- 4 General Industries businesses develop, manufacture and market energy products and systems including flow control and distribution products for utilities; and components for the oil, gas and nuclear industries and graphics, textile and power tool products including high-speed presses and related graphic arts equipment, textile machinery and power tools.

The Utility Communications Systems (UCS) effort is under the direction of the Municipal and Utility Division (M&U), which is a part of the

Energy Systems Group, a part of the General Industries business of Rockwell International.

### UCS Venture

The UCS venture is organized as a small business under the management of the Municipal and Utilities Division. The structure is similar to any small business of its size having a director, seven group heads, and staff. An organizational chart is shown in Fig. 1. The director reports to two review organizations. One was associated with M&U, the other was with Rockwell Corporate. Rockwell Corporate formed what might loosely be termed a board of directors for the effort. The board is made up of individuals from various divisions and groups within Rockwell. The groups within the venture were production, marketing, product engineering, system integration, purchasing, business planning and operations, and research and development.

### Technical Nature of the UCS Product

The UCS effort was originally based on the premise that electric utilities were searching for ways to avoid the necessity of building new power plants. The economics of scale situation which existed through the 50's and 60's was no longer valid. The utility was, in general, doing all it could to increase the efficiency of its generation facilities. It was also attempting to lower its losses in the transmission area by intelligent dispatching. The only part of the equation over which the utility had no control was the customer usage part. The ability to "dispatch" load would add a new dimension to the ability of the utility to control the requirement for new "plant" thus avoiding the need for construction capital.

About this same time, utilities were falling under more active regulation from local and state regulators. Thus they were encouraging utilities to implement time-of-day rate schemes and minimum billing schemes which the regulators viewed as effective means of attempting to move system peaks. Before any judgment could be made on the effectiveness of such "voluntary load management" methods, some data had to be

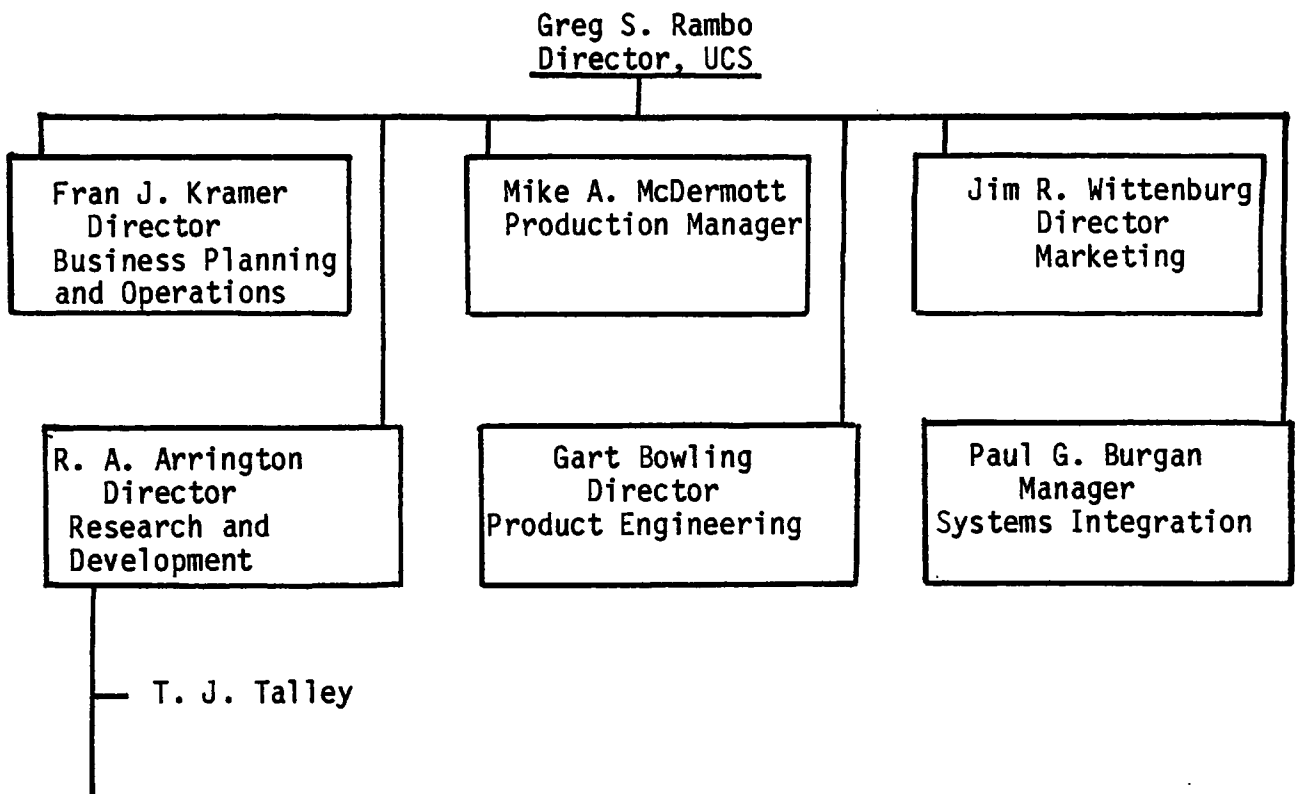


Fig. 1. Rockwell UCS organization.

taken at the residence to support conclusions by the utility or the regulators.

The Rockwell distribution power line carrier system was originally intended to provide two basic services.

- 1 It would allow the utility to implement time-of-day metering and acquire data as to the effect of that billing method on the customers.
- 2 It would allow the utility to implement "active load management" on certain customer loads. (i.e., electric water heaters, and air conditioning compressor units.)

The data from both of these experiments could be compared to determine the potential optimum rate and control balance which would yield maximum reduction in plant requirements, and would produce minimum customer dissatisfaction.

To accomplish these functions, it was necessary to have a communication link directly between the customer's equipment and the utility headquarters. Many methods might be used to accomplish this, but one of the most challenging, and potentially rewarding was the method used by Rockwell. The distribution power line carrier concept should be particularly interesting to the utility since the communications medium (the power line itself) has already been run to each customer. The utility has only to use it as a "transmission line" to be able to communicate directly with each customer. Additionally, the Rockwell system would allow the natural gas suppliers, like Pacific Gas and Electric, to be able to read the gas meter remotely. Municipal utilities should also be able to read the water meter if they desired to do so.

Now that the utility had this system which could communicate between the substation and the customer, it might also desire to perform some control functions on the distribution system. This last statement is a description of the need which, when formalized, becomes the functional description for "feeder automation systems."

The actual method of communication on the distribution lines involves injecting a current in the 5 kHz range at the substation or residence and varying the phase of that current to encode the intelligence to be transmitted. The modulation technique is called DPSK

(differential phase shift keying). It is a very narrow band, synchronous communications technique whereby the power line 60 Hz voltage itself provides the synchronous reference frequency.

The information thus derived at the substation is passed on request to the central computer which accumulates and tabulates the data from all substations. A pictorial description of the system is shown in Fig. 2.

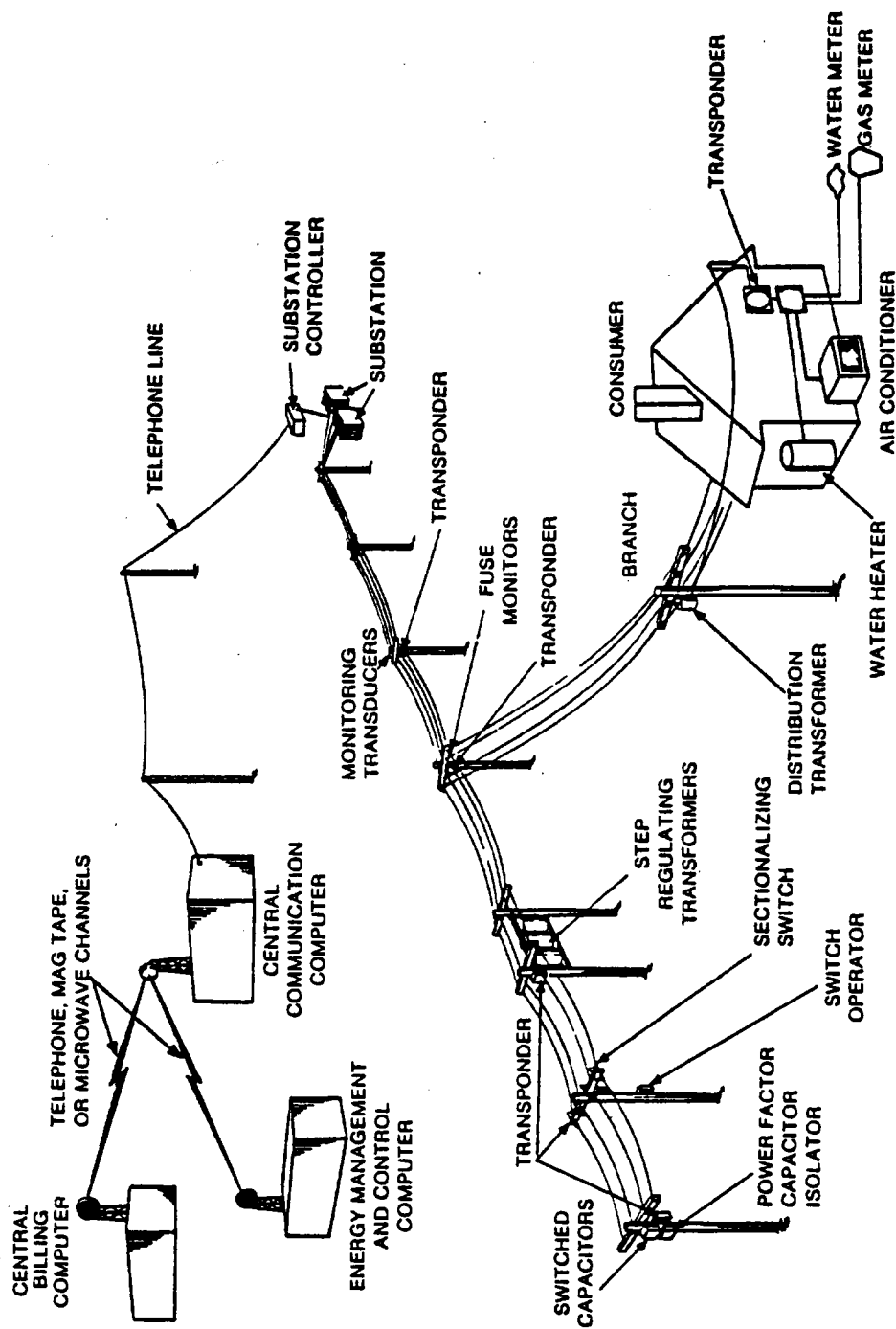


Fig. 2. Rockwell power line communication system.

## BACKGROUND OF THE CANDIDATE

Most of my formal education has centered around the electrical/electronics discipline. The internship situation at Rockwell UCS presented a unique set of challenges which it seemed I had been preparing for my entire career. That may be true of most challenges in one's career, but this incident seemed particularly explicit in that regard. In brief, Rockwell needed an engineer who (a) had utility experience, (b) had communications experience, (c) had microprocessor experience, and (d) who would help guide the development of a high technology product from concept to product. I include the following descriptions of my education and experience followed by a detailed description of Rockwell's needs to share with the reader that feeling of destiny which I previously mentioned.

### USAF Electronics Maintenance

In late 1964, I entered the United States Air Force. For the next two years, I was directly involved in electronics fundamentals training at Keesler AFB, Biloxi, Mississippi. I participated first as a student, then as an instructor in the maintenance and operation of heavy ground RADAR systems. The training included some 1750 classroom hours of instruction in subjects ranging from D.C. circuits, to a detailed study of RADAR transmitter/receiver systems.

The training received would be categorized as vocational in nature in that it allowed me to understand the principles involved sufficiently to maintain the equipment. This fundamental training in heavy ground RADAR systems was followed by 2 years of field maintenance experience while stationed at McChord AFB, Tacoma, Washington. At McChord, I also became familiar with other types of electronic equipment in addition to the RADAR systems mentioned earlier. Airborne RADAR and navigational aid equipment were also placed in my area of responsibility. This equipment included voice omni range (VOR), tactical air navigation (TACAN), IFF/SIF, marker beacon, and long range navigation system (LORAN). These various systems employed a considerable variety of modulation and detection techniques.



### Communication Vocation/Avocation

During my Air Force career, which lasted for nearly 4 years, my interest in "electronics" in general and "communications electronics" in particular, began to emerge. I began many small electronics projects, including some rather significant general coverage receiver kits. One of these led me to an interest in amateur radio. The amateur radio "hobby" has led to experimentation with a multitude of antenna, feed-line, modulation, and detection techniques. In fact, my present day amateur station is capable of unattended packet switching duty using a small microcomputer and VHF receiver/transmitter arrangement. In summary then, my formal "vocational" training in the Air Force was supplemented by my continuing interest in electronics and communications. This growing interest led me to undertake the undergraduate Electrical Engineering curriculum at Texas A&M University when my active duty tour was completed. The availability of the GI Bill assistance played a key role in my being able to attend school following my military service. Without it, I would not have been able to attend college.

### Undergraduate Electrical Engineering

Having completed my active military career, I entered Texas A&M. The electrical engineering curriculum at A&M allowed a minimum of electives with which to specialize. I selected one in power systems, and one in digital systems.

By the time I was ready to graduate, I had not decided whether to pursue a "high-tech" or a "utility" career. Therefore, I interviewed both utility and high-tech companies. I selected Texas Electric Service Company (an electric utility company) of Ft. Worth and began work in early 1972. TESCO seemed very interested in the fact that I had not chosen to "specialize" in electrical or electronics, but had pursued both. They seemed pleased that I was interested in not specializing, but in finding ways to apply high technology to the problems faced by the utility industry. They pointed out that before I could set about solving all the industry's problems, it would be helpful if I understood a few of them. They began to immediately educate me.

### Utility Experience

In early 1972, I began work for Texas Electric Service Company (TESCo). TESCo is a wholly-owned subsidiary of the Texas Utilities Company system. The Texas Utilities system is made up in part by three operating utilities. The other two operating companies in the system are Texas Power and Light company, and Dallas Power and Light company. These three operating utilities provide electric service to about 1/3 of the state of Texas. TESCo serves communities in the geographical area bounded by Arlington/Grand Prairie on the East, Wichita Falls on the North, and West to the Permian Basin area about 100 miles East of El Paso.

My first assignment at TESCo was in distribution engineering in the Ft. Worth division. This work included designing (using approved engineering practice reference manuals) overhead and underground distribution systems. This assignment was followed by commercial industrial sales work which involved detailed determination of customer needs. These customer requirements were transmitted to engineers who insured that service was provided when the customer required it.

These distribution assignments made up my first 3 years of experience at TESCo. They were followed by general administrative, personnel and supervisory positions. In mid-1977 I had been out of the "engineering" business long enough that I was finding it difficult to understand the articles on my profession in general publications. The Hewlett Packard HP-35 hand-held calculator had been available for \$389.00 when I had been a senior at A&M. Calculators were not allowed in many classes since most people couldn't afford one. I had graduated at the beginning of a technology revolution and had been rapidly outdistanced as I was developing my understanding of the utility industry.

This period was also the period when Linda (wife of 12 years at this writing) and I were beginning our family. It was not possible for me to catch up on such rapid technology advances through home study. Therefore, I decided that I would return to school and pursue a Master's Degree in Electrical Engineering. In so doing, I hoped to become cur-

rent with the state of the art and to be able to take courses which would add to my understanding of the operation of other areas of the company as well (financial, organization, political, etc.) In May 1977, I returned to Texas A&M and enrolled as a graduate student half time. The other "half" of my time was to be spent as a graduate research assistant in the Power Systems Automation Lab.

### Graduate Studies

As a graduate student associated with the Electric Power Institute, the majority of my course work was involved with power system studies of one sort or another. Subjects included were power system analysis (load flow, transient analysis), relaying and protection systems, transient testing, reliability analysis, and control and dispatch philosophies to mention a few. Other non-power system work included math and microprocessor fundamentals. It became apparent that there would not be room in the master's program for all the nonengineering courses I wanted to take. The Doctor of Engineering curriculum provided an excellent alternative to abandoning the MS route for an MBA. I chose to continue the MS program and then complete the remaining requirements for the degree of Doctor of Engineering.

### Advanced Power Systems

The detection of downed power lines has plagued the utility industry for years; I chose as a Master's Thesis subject the analysis of the high frequency currents present on the power line as it contacts an "earth" (non-bolted) ground. These studies involved numerous field trials. Several utilities participated in the experiments which are described in great detail by Aucoin (1981). In fact, Mike Aucoin and I worked as a team under Dr. B. D. Russell to develop a microprocessor-based relay which could detect downed power lines. I analyzed the signals and Mike used my analysis to develop algorithms for use by the relay. The resulting relay was recognized by the National Society of

Professional Engineers as one of 10 Outstanding Engineering Achievements of 1981 (Arcing Fault Detection System, College Station, Texas).

### TAMU Power Systems Automation Lab

There were other activities were going on in the lab also. Seven graduate students shared lab and office space, so a considerable amount of problem/knowledge/work sharing went on. Two major projects in addition to the arcing fault relay were in the lab during this period. One project involved the use of electric and magnetic field measurement equipment to characterize the fields associated with various switching phenomena in transmission substations. This work was to provide a data base on which to make judgments about shielding requirements for electrical/electronic/computer equipment which might have to survive the harsh electrical environment in the substation. The equipment necessary to make these measurements was identical to that required to study the electrical effects of a nuclear blast.

Measurements were made at a number of transmission substations. All members of the lab participated in the preparation for and accomplishment of these tests. The data collected were provided to the Electric Power Research Institute (EPRI) for the use of the utility industry and its vendors. The capability of the lab to measure electrical phenomena lead EPRI, Northern States Power, Minnesota Power and Light and Ontario Hydro to invite Texas A&M to assist in taking data at the first field test of a 400-mile long 500 Kv transmission tie between the U.S. and Canada.

Low frequency measurements (D.C. to 80 kHz) were made of ground potential substation voltage rise during faults. Low frequency measurements were also made of the induction fields adjacent to the transmission right-of-way during faults and switching operations. High frequency (100 kHz to 100 MHz) measurements were made of switching transients, and fault created fields.

In summary, my career had led me from a vocational interest in communications and electronics, through the distribution engineering role in an electric utility, to a high technology product development role at the EPI lab. These experiences and educational interludes were

precisely those which Rockwell was seeking to assist them in developing their distribution power line carrier effort. Consequently, I was offered, and with the concurrence of my committee chairman, accepted a position as Senior Systems Research and Development Specialist with the Rockwell Utility Communications System venture.

## ROCKWELL'S NEEDS

Rockwell's Utility Communications Systems venture was staffed by individuals from two principal divisions of Rockwell. Most of the electronics people came from the Rockwell/Collins Electronics Systems Division. The utility people came from the Municipal and Utility Division. The electronics specialists had a significant amount of experience in military contract work related to digital and analog communications in hostile environments. The utility people came from the division within Rockwell which provided water meters to municipal utilities. None of the people associated with the project had ever worked for an electric utility. They recognized their lack of experience in the electric utility area, and subsequently sought to rectify that situation by hiring an individual from within the utility industry.

### Advanced Degree

The electric utility specialist Rockwell required had to have a comprehensive understanding of all the technologies involved in the use of distribution power line carrier signals to control customer electrical loads and to measure customer electrical use. The technologies and applications include electric utility distribution construction practices and their effect on transmission of power line carrier frequency signals; microprocessor software/hardware configurations and their effect on the intelligence of the systems using them; advanced modulation/detection techniques; and methods of developing system level functional descriptions for advanced systems using existing and easily achievable technology.

Rockwell felt that the individual who could enter their project and contribute at the appropriate level would, of necessity, have to be educated to the Ph.D. level or have equivalent experience. Rockwell also wanted the individual to become a "technical spokesman" for the UCS effort and thus felt that an advanced degree would lend greater credibility to the studies and reports issued by the group.

### Utility Experience

The experience which Rockwell had in developing and implementing systems for use by the military left them unprepared for the expectations they faced in their first major attempt to market systems to the electric utility industry. This was particularly true since the system which Rockwell was developing used technology which the utility industry viewed with some skepticism. In order to understand "utility thinking" the individual Rockwell wanted to assist them in the development of their business would have to have considerable experience in the electric utility.

### Communications Experience

Rockwell's advantage was its experience in communicating in "harsh" electronic environments. Rockwell had developed several communications systems of this type over years of developing military systems. UCS felt that advanced communication techniques could enhance the capabilities of their systems so that a minimum of hardware would have to be added to existing power lines to support successful distribution power line carrier (DPLC) operation. This minimum hardware addition would be a major competitive advantage for Rockwell.

The engineer who was to integrate these advanced communication techniques into the utility system would have to have a complete understanding of them. He would also have to be able to relate the appropriate knowledge to his colleagues in the utility industry in terms of customers' needs.

### Microcomputer Experience

In mid-1980, Rockwell had completed several iterations in the technology it intended to use for UCS. The last was a large-scale integration of many of the receiver functions used in the remote load control receivers. The use of the capabilities of the microprocessor was critical to operation of the advanced/economical system UCS was evolving. The power and limitations of the microprocessor had to be understood by

the engineer Rockwell needed. The engineer was to develop new uses for the tools UCS was rapidly acquiring. To efficiently do that, the engineer had to understand first the utility system needs, and then the capabilities of the system which Rockwell used to satisfy those needs.

### R&D Oriented

The Rockwell Utility Communication System is a fundamental communications system using a distribution power line carrier to communicate control commands from the utility to customer equipment, and customer information to the utility. That role is a small sub-set of functions which should be integrated into a full "feeder automation system." Part of the engineer's duties would be to formalize the concept of the feeder automation. This would involve developing new system plans, prototyping new equipment, proposing, funding, and managing prototype systems projects.

The engineer would also support the day-to-day R&D activities which were out of the ordinary "engineering" tasks. These would include new product testing, report writing, assistance to marketing in proposal submittals and the like.



## INTERNSHIP AT ROCKWELL INTERNATIONAL UCS

In March, 1980, Dr. Russell was contacted by Rockwell in search of an individual to fulfill their needs as outlined in Section III of this report. They wanted an engineer with an advanced degree in electrical engineering, with utility, communications, microprocessor and new product development experience. My background as outlined in Section IV of this report, was known by Dr. Russell and he recommended that Rockwell consider me.

I was interviewed by Mr. R. A. Arrington, Director of Research and Development for the Utility Communications Systems operation. He offered, and I accepted, a position as Senior Systems Research and Development Specialist. I accepted with the provision Rockwell support my Doctor of Engineering work, and that Mr. Arrington become my internship supervisor. He, Dr. Russell and I agreed that the systems work which I performed for Rockwell would be structured in such a fashion as to meet the requirements for the D.Eng. internship.

### Objective

There were two primary objectives set, and accepted by me for the internship experience. One objective was quite specific and dealt with a system product. The other objective was of a more general nature.

- 1 Develop the concept of feeder automation into a prototype system and test it.
- 2 Provide general technical support to on-going UCS activities.

### Position

The position to which I was assigned was titled Senior Systems Research and Development Specialist. A summary of the job description is listed below.

Position description: Senior Systems Research and Development Specialist

Function: Develop state of the art electronic products for use in the Utility Communications Systems Market. Perform substation and distribution system studies for maximizing data thruput and reducing error rates. Develop concepts and product definitions for increasing communication reliability on the power line.

Job Requirements:

**Education:** Ph.D. in Electrical Engineering.

**Experience:** 6-8 years of directly applicable engineering experience in both communications and power systems, systems integration, equipment development and technical management including:

- Analog and digital modes of communication, data collection, processing and control;
- Telephone, power line carrier, radio, microwave and optic communications media;
- Electric power system operations and control, capacitor banks, load tap changing transformers, feeder characteristics and substations.

**Special Abilities:** Competent to perform assignments in specialized field of highly advanced and sophisticated nature. Understand and utilize modern communication and decision theory. Capable of solving abstract problems that are difficult to define and the solution for which may require use or development of advanced theories, principles and concepts. Often required to solve problems with no precedents and to develop information that extends the existing boundaries of knowledge in the field. Identify R&D programs and projects for development of new products consistent with long term UCS goals. Patented and published in the field.

**Accountability:** Plans R&D programs and recommends technological applications programs to accomplish long-range objectives. Acts independently to uncover and resolve problems associated with the development and implementation of operational programs. May be virtually self-supervisory.

### Major segments of position:

1. Study and analyze power line communications to identify potential weaknesses and make recommendations for corrective action.
2. Perform studies of substation and distribution systems to develop concepts and equipment for control of distribution system under varying configurations.
3. Performs specialized studies for Utility Communications System.
4. Identify R&D programs and projects for UCS.
5. Makes presentations to potential customers in support of PLC Marketing.

### Technical Nature

My function within the organization was a staff function. The function of the R&D group was, in general, a staff function. That is, the R&D group performed research for and advised top (line) management on matters of interest to venture management. We advised the field service group on matters related to general technology. We advised the engineering group on matters concerning specific design problems. We advised management on matters of technical and industry interest. We advised marketing on matters such as the possibility of use of existing or proposed equipment to satisfy customer requests.

The authority by which the R&D group influenced the operations in other areas was primarily derived from the power of expertise. Both the director of R&D and my associate R&D specialist (W.C. "Bill" Perkins) had been with the project from the outset. Both are highly respected engineers who were consulted at every opportunity by field and engineering personnel. In fact, these consultations began to interfere with the other work of the R&D group to an extent that efforts had to be made to insulate Bill from the near-constant interruption he suffered.

My utility experience led to my being consulted occasionally about the "utility" way of doing things. My advanced degree work yielded sufficient respect from the technical members of the project that I was treated with the utmost courtesy and consideration while on information

gathering missions for the feeder automation system design effort. My communications background enabled me to gain the respect of my co-workers in the R&D group as well as other project staff. This respect allowed me to participate in many fruitful discussions and experiments from which I might have been otherwise excluded. These activities brought my understanding of the system along very rapidly.

### Theoretical

The theoretical aspect of the assignment covered a broad range of engineering and management knowledge. One rather fundamental set of calculations involved a device called a capacitor isolator. The device is an epoxy encapsulated inductor which is used in the neutral of power factor correction capacitor banks to raise the impedance of the bank to the signal frequencies used by UCS. In order to specify the amount of current the inductor would have to survive, it was necessary to calculate the amount of current it would be subjected to during "inrush." The  $I^2t$  specification for the device was thus provided (see Appendix A). The value found in the  $I^2t$  calculation was used as a specification reference for the generation of a test plan. I wrote the test plan for, and supervised the test of, several prototype devices which were tested at the McGraw Edison high voltage test laboratory in Franklin, Wisconsin.

The tests involved both high voltage transient gradient and high current  $I^2t$  measurements. Several devices were tested to destruction. The results of the tests were used by me and the director of R&D to evaluate the potential of the product for future use.

A more complex challenge was the development of the feeder automation system. As will be described in detail in sections V.C. and V.D of this report, the development presented significant technical challenges. The first of these challenges, and perhaps the greatest, was to define what the "industry" meant when it used the term "feeder automation." No clear consensus existed in the literature or the industry, so some effort had to be made to define the system. Once the system was defined functionally, the next challenge was to satisfy the functional requirement by using as much of the existing UCS technology as possible. This

meant that I had to achieve a thorough understanding of the operation of the UCS power line carrier system.

Once the functional definition had been refined, and the existing technology understood, what amounts to a design specification had to be prepared. This would outline by what method, using existing technology, each requirement of the functional requirement would be met.

Another project involved the design of a system to measure the communications between substation transmitter/receivers and the remote customer transponders. The system was to measure and record the transmission of signal current as it passed by some intermediate point. This was to assist field personnel in diagnosing the cause of communication problems in a particular area. The system was to involve the use of current transformation, frequency modulation (or pulse code modulation) and a wide band recorder to achieve the acquisition and recording requirement. The tapes thus made could be analyzed on site or returned to the shop. The decoding of the information on the line would be done by a microcomputer-based system which was to be produced by another Rockwell facility.

### Customer Relations

One utility customer which had a significant UCS system installed, was experiencing some Radio Frequency Interference complaints in an area served by the UCS system. I had been involved in RFI source searches before, both at Texas A&M and Texas Electric Service Company. Rockwell asked that I assist the customer in an effort to determine if (a) the UCS system was contributing to the problem, and (b) if the problem was contributing to the poor communication success rate which was being experienced at times by the UCS in the same area.

I assisted personnel from the utility in searching for and correcting as many "noise sources" as possible. Upon completion of the effort, I wrote a report to the utility suggesting that they review their 25 kV construction standards. Most of the noise was caused by loose pole hardware, particularly that hardware which relied on pressure from the wood pole to maintain tension. The line involved had been constructed for some time and had been reinsulated for higher voltages every few

years. The last upgrade had moved the line to the 25 kV class. At that voltage level, significant voltage stress is placed on oxide layers between metal parts near the lines. TESCO found it necessary to use spring loaded washers to increase the tension on hardware and insure that a minimum noise generation potential existed. The Rockwell customer had not done this to the line in question. As a result, when the temperature varied, or the wood pole compressed under the force applied by the hardware, the hardware became loose and the noise-causing oxide layer began forming. The problem could be temporarily cured by retightening the hardware, but noise would occur again after a short period. I indicated this to the utility during my visit and in my report. I do not know if my recommendation was followed. Since all the noise sources in the area were not "cured," I do not know if they were contributing to the poor communication success rate which was a periodic problem in the area.

### Specific Assignment Task Analysis

My specific assignment was as previously outlined in the internship objective and job description. Developing the feeder automation plan was a continuous foreground task, which was interrupted occasionally by other projects. The automation plan was a rather solitary duty. It required only occasional discussions in the engineering department and with fellow R&D personnel to discover some aspect of the existing system which I did not understand. The task analysis was performed and schedules set for the completion of each task.

### Develop Feeder Automation Concept

I was instructed to use whatever means I felt were appropriate to define feeder automation. After a significant amount of review, I suggested that what was needed was for that utility industry to tell us what "they" meant when they identified the concept. As a result of my suggestion, a utility advisory group was invited to Dallas to participate in a two-day session. The function of the session was to arrive at a consensus concerning what feeder automation should be. So my first

task was to correlate the data received from the utilities to define the feeder automation concept.

### Develop Feeder Automation Project Plan

The project plan was to be developed from the understanding of the technology used by Rockwell and the understanding of feeder automation as derived from the utility advisory group and the literature. The ultimate plan included functional specifications and a schedule for implementation for the project.

Scope of Feeder Automation. There is a lot of discussion in the industry concerning the scope of what is called "load management." The same amount of discussion rages over what constitutes "distribution automation." For the subject at hand I adopted the following general guide definitions. Load Management consists of two parts: voluntary load management and involuntary load management. Both voluntary and involuntary load management attempt to manipulate the customer's use of electric energy. The voluntary method attempts to use coercive rate structures and public media in order to influence the customer to modify their pattern of use of electricity. Involuntary (sometimes called active) load management is when the company is able to and does turn certain customer loads off.

Distribution automation is the field which relates to control of all distribution equipment. That equipment within the substation is controlled by equipment which is termed substation automation equipment. That equipment which is beyond the substation fence is termed feeder automation equipment. Note that active (involuntary) load management equipment is beyond the substation fence and is thus of the genre of feeder automation equipment.

Now that the definitions are straight, the next task in determining the scope of the feeder automation plan had to do with determining what things are to be done on the distribution system which are beyond the fence. A quick reference to Fig. 1 again shows that there are numerous equipments along the feeder which affect its operation. The customer end of the business has been taken care of nicely by the UCS, so the

references to feeder automation from this point on will address only those functions from the substation fence to the customer transformer.

Identify Support. It was obvious that the development of a new system of the complexity of the one considered as a feeder automation system would tax the resources of the existing UCS personnel beyond their limit. Therefore, it was necessary to identify additional sources of technical capability both within and from outside the Rockwell businesses.

Identify Cost. The cost of developing the feeder automation system depended entirely on the performance levels required and the schedule by which resources could be made available. No effort to scale the cost was made at the outset, since such an estimate would not have been appropriate. An order of magnitude was considered to be high hundreds of thousands of dollars.

Identify Host Utility. Several utilities which already had Rockwell powerline carrier equipment installed expressed an interest in having a trial feeder automation system developed using their systems.

Each utility had its own method of operating its distribution system. It became apparent that it would be necessary to find some consensus within the industry about what a feeder automation system was and how it should be able to operate. In order to reach this consensus, Rockwell sponsored a meeting of what was later identified as a Utility Advisory Committee. The function of the committee was to assist Rockwell in identifying the functions which the system should perform.

Prepare and Submit Proposals. The feeder automation system had to be defined functionally and technically to the point where UCS had a high confidence level that the functions could in fact be performed by the hardware identified as being required. Initial proposals included a minimal experimental system to measure and control voltage on the feeder. The complete definition of the system was not accomplished until after the Utility Advisory Committee was formed and had met with UCS staff.



### Propose System for Funding

Funding an R&D effort of this nature is a real challenge. It is particularly a challenge in the electric utility industry. This issue became one of the biggest areas of contention between venture management and me. The experience which Rockwell had in performing R&D for the military led them to believe that the utility industry had discretionary funds in R&D budgets similar to those budgets within commands of the armed forces. They did not seem to understand that regulated monopolies cannot and do not spend R&D money quickly on the basis of a proposal from a would-be vendor of equipment.

The utility industry has established an entity to take care of these kinds of things for it in an orderly manner. That entity is the Electric Power Research Institute (EPRI) which is located in Palo Alto, Claifornia. Therefore, several proposals were to be submitted, and EPRI was to receive one.

### Implement System on Prototype Scale

Assuming 1 and 2 above, the next step would be to implement the plan in a prototype system and test it. The test was designed to produce several evaluations. First, would the system actually work (fast enough, reliably enough, flexibly enough, etc.)? Next, did the user gain better direct control over those systems he wished to control by using the system? Finally, what would be the cost, schedule and performance of a full-scale installation?

### Assist On-going UCS Activities

Several UCS R&D efforts were underway when I arrived. A few were initiated during my stay. Direct and indirect participation in these efforts consumed the remainder of my time while at Rockwell. A few of the projects were:

- 1 Capacitor isolator product evaluation
- 2 Radio receiver test and evaluation
- 3 RFI study for customer

## Administrative Assignment

The principal administrative duty was to assist the director of R&D in the preparation of the 1981 strategic business plan.

The plan evolved over a two-week period of continuous work. The effort began with defining the tasks which R&D felt were necessary to support the on-going UCS project. The tasks were identified in Gant chart format and estimated manhours and equipment budgets for each task assigned. The resulting manpower projections and equipment budget proposals were combined into an operating budget summary. That summary was submitted to the venture director, who presumably incorporated it into the project budget.

Several weeks after the budget submittal, the members of the venture accounting staff reviewed in detail each of the budget items with the director and me.

While all of this sounds like a simple budget process, the position of the R&D department must be remembered. We were the ones who had sponsored the utility advisory committee effort. That was one activity which allowed us to see the customer's desires very clearly. We worked very closely with marketing in the preparation of proposals so we understood what kind of specifications were being issued by the customers for our kind of equipment. We worked closely with the field service personnel on particularly sticky communications problems and therefore had an excellent opportunity to evaluate the overall system performance and its weaknesses. We attended IEEE conferences and assisted section chairmen in related fields, and thus met and talked to utility personnel who were directly interested in "load management-feeder automation equipment." As a result, we knew how well the competition was doing on their trial system installations.

So, the task analysis prepared by R&D was a compendium of understanding of the marketplace, our place in it, and the apparent desires of the customer. Several contingencies were evaluated. Maximum and minimum effort budgets were prepared to indicate that the UCS R&D effort would accommodate changing market requirements. In fact, the entire budget was modular. That is, each task carried its own schedule of

expenditures. If the situation warranted, the task, and hence its proposed expenditure, could be advanced or delayed in response to external pressures.

### Sources of Information Required

The information necessary for me to understand the communications system techniques used by the UC system was contained in the patent descriptions for the Kineplex system. The patent was issued to the Collins Radio Company during the 1950's. The actual technique is a differential phase shift keying (DPSK) modulation technique which in the early stages of the project was biphase and later quad-phase DPSK. The real advantage of the technique is that it is synchronous, that is, the transmitter and receiver both know over what period to listen for each data bit. This is achieved by using a harmonic of the power line frequency as a "pilot" or standard frequency. An additional advantage of the system is that the nulls of the detectors are invariably placed on the 60 Hz harmonics adjacent to the signal frequency thereby improving the communication probability with very little penalty to the system.

### Internal Rockwell/Collins UCS documents

When Rockwell purchased Collins Radio in the early 70's, the Kineplex patents came in the transfer of technology. An extensive private technical library also exists which contains the internal papers written by Collins-Rockwell/Collins engineers on various communications subjects. None of those documents will be referenced or quoted in this report. The patents, which are public, are a substantial source of information.

### Industry Papers

Several papers on load management and automatic meter reading had been published in the power apparatus and systems journal of the IEEE.

Mr. Arrington had written a paper on load management and automatic meter reading using power line carrier. These papers formed the basis of my understanding of the "state-of-the-art" in the load management world. A few very speculative articles about what "distribution or feeder automation" might be were written in some major manufacturer's in-house magazines, but no major definition of a consensus as to what feeder automation was or what it should do emerged from the literature.

### Conversation with Utility Representatives

Technical meetings presented an excellent opportunity to discuss a broad range of topics with individuals of similar interest. Engineers from utilities which were considering the use of load management/feeder automation equipment spent a great deal of time and effort trying to understand the state-of-the-art and its potential use. They were very inquisitive about the Rockwell system and returned any information given with information of their own about how they intended to use the system in the future. A lot of "what if you could..." type discussions led to a general understanding on my part of what the industry wanted.

### Experience

I was an active designer and user of distribution systems for some years at TESCO. My experience contributed significantly to the general understanding of utility practices.

### Utility Advisory Committee

The utility advisory committee was formed to provide input to the UCS staff directly from those members of the utility industry who were intending to use the equipment under development. However, as pointed out in the next section, even if the advisory group couldn't reach a consensus, their input contributed strongly to Rockwell's understanding of utility needs.

## EPRI Reports on Test Projects

At the time I was doing my research and system design, there were two major projects under way in the field of "substation automation." Both these projects were sponsored by EPRI. No data was available from either of the projects at that point. The two projects bordered on the use of feeder automation techniques and therefore were of some interest. There were also some other EPRI sponsored projects on load management and automatic meter reading which were nearing an end.

It appeared at the time, that we were close enough to the state of the art that there was not likely going to be anyone to "learn from." We would just have to take the information we had and do the best we could.

## Information Required But Not Readily Available

All of the fundamental communication information was available. All of the information on load management was also available. Precious little information was available on the definition of the scope and function of feeder automation. The company formed the utility advisory group (UAG) to try and generate the information, and in a way that effort was more successful than we at first thought. The UAG did identify the functions an integrated feeder automation system should be able to perform, but they could not agree on which small subset should be placed on priority for development.

## Administrative and Managerial Activities

The planning function at Rockwell had already passed through the strategic level before I arrived. The logic involved in the selection of the venture from among alternative programs went something like this.

Military contracting is shortrange and high risk.

Rockwell has 30-40% of its business tied up in military contracting.

The utility industry is much more stable (from Rockwell's experience with valve and water meter sales), so why not stabilize business by developing another business area associated with utilities. The technical scenario described in this report then led Rockwell to decide (plan) to develop the UCS operation.

The next level of planning got down to tactics. How do you get the system going technically? How do you get the system funded? How do you get the system designed? How do you evaluate the desires of the potential customers? Each of these questions (and many more) were addressed in some detail.

My part of the program was limited to the project known as the Feeder Automation System. I was responsible for the work breakdown structure (task analysis) which appeared earlier. Following the task analysis, I estimated the resources necessary to perform each task. The resources (hardware, capital items, and people of the appropriate technical level) were all available from within the pool of the Rockwell/Collins operation. I did not reach the "staffing level" since the project was never funded. The criteria by which the project would have been staffed had been pretty well set (level of competence, number of people).

I was a team member, not a team leader by definition. My roles were limited to the Informational and Interpersonal. The monitor/disseminator/spokesperson roles were performed when I attended meetings in an attempt to gather an understanding of what the industry wanted from a feeder automation system. The liaison/leader/figurehead roles were how I accomplished the creation of the utility advisory group. I was the "token" utility guy on the project. It became apparent to me that my own convictions would not be enough to convince the program staff of a fruitful future course of action. I proposed that the UAG be formed and convinced the appropriate members of the project that it was in their interest to do so. This liaison role expanded when the UAG was actually formed, as I was able to invite individuals I knew to participate. The decisional roles were handled by Mr. Arrington. I was not assigned to directly supervise any employees. Therefore, I did not have any administrative duties normally associated with supervision.

The evolution of my activities is recounted in some detail in my monthly internship reports which are contained in Appendix A.

The most significant administrative duty to which I was assigned was the preparation of the Strategic Business Plan and associated budgets for the R&D group. This was done in close coordination with the director of Research and Development and under his direct supervision.

### Contributions to Areas Outside Direct Assignment

The function of the R&D group was to support the future of the project and help any function in the project that needed help to support the "today" of the project. I was part of the R&D effort, so that character fell to me as well. We/I assisted marketing in the preparation of proposals. We assisted engineering in improving the performance of the communication system by the addition of the resonated capacitor isolator. We assisted field service by providing guidance in the diagnosis of problems in communication success rate with installed systems. We assisted field service by assisting the customer utility in diagnosing Radio Interference sources. We assisted purchasing by testing and reporting on deficient lots of equipment sent to us for use by vendors. In addition, we wrote test plans which could be used in the future to insure that poor quality lots of material were not accepted.

### Non-technical Problems

#### Human Relations

The most difficult and ultimately the most rewarding relationship I had during my internship was with my internship supervisor Mr. R. A. (Bob) Arrington. Bob is a very task-oriented manager, and I am a very people-oriented type person. Our styles were in direct conflict. Bob is a former submarine commander. I am a former pipeline superintendent. Each of us felt that we were capable, independent individuals. As a result, as my effort proceeded, Bob felt that I needed more structure in my time management and thought processes. He began reviewing my work in smaller and smaller batches. This type of activity was very frustrating

to me in that I was used to being given general direction and then the success or failure of my efforts judged by the ultimate outcome. Bob felt that he needed much more control over the path of my progress than that. We discussed this difference often in an attempt to reach some middle ground suited to both of us.

Bob wanted feedback regularly so that he could modify the course of progress with whatever new insight he might have. I wanted the satisfaction of being able to complete the work in a relatively unfettered manner. I was particularly frustrated by the course modifications which inevitably resulted from the review sessions.

The most pleasant part of the internship experience was when Bob and I discovered a method/style which worked well for both of us. It was what might be termed the "corner of the desk" approach. Essentially, the problem had been one of delay in the feedback system. Bob would instruct me to perform a task which was a subset of some project. I would go away and later return to review my progress in that task. Based on new understanding of the project, and the results, Bob would restructure the task which I had just performed and assign it again.

When Bob and I concentrated on tasks together, and reduced the period between reviews, the problem vanished. Bob got his immediate feedback, and I got the gratification of working with him on a project of mutual importance. This approach used a considerable amount of both our time in the beginning. However, once the projects we were working on were clearly enough defined that Bob and I both had the same understanding of not only what was to be done but how as well, I could go away for longer periods and the work progressed much more rapidly.

This technique was used very effectively during the strategic business planning period. While the intense/interactive planning period lasted only a matter of 3 days, the actual preparation of budgets and task descriptions went on for weeks. Bob seemed pleased that I was working closely with him on the initial stages of detailed problem definition and solution planning. I was pleased that my contributions were subject to immediate feedback so that unproductive excursions along undesired paths could be held to a minimum. I am convinced that this experience alone was worth the nine-month internship. Searching for and finding a method which allowed two very diverse personalities to work



together productively was very rewarding. I leave to Bob any discussion of his observations during that time. I think I reflect his feeling however, since we discussed the situation often.

### Limited Utility Experience of Staff

Many of the individuals of the staff of the venture had never been exposed to the utility industry to any great extent. A few notable exceptions were the venture director who had sold metering equipment to the industry for some years. The southern region marketing director had also had previous marketing experience as a vendor to the industry. No member of the staff had ever worked for a utility. Some of the electronics types found utility practices hard to understand and appreciate. The fundamental conservatism which is imposed by system reliability requirements was something few people outside the industry could understand. The feeling that "the lights must not go out," seemed to shock some of the venture personnel. Reliability, accuracy, simplicity, and flexibility were the watchwords by which the systems had to be designed and operate.

### Critical Resource Allocation

The "home office" for the venture was located at Municipal and Utility division headquarters in Pittsburgh, PA. The directors of the venture and the accounting staff were located there. The remainder of the effort was located in Dallas to take advantage of the resources available from the communications/electronics businesses located there. There were no people with utility experience, or with major system marketing experience, or with major computer system design experience or with sophisticated communication system implementation experience at the home office. As a result, the project reviews which occurred there on a casual basis did not reflect the technical realities which were apparent to those closer to the work. This is a problem if the home office is across the street. So, distance is not the only reason for this seeming insensitivity to technical reality.

As a result, decisions on budgets and critical resource allocation were made with minimum consideration for the impact which they had on anything but the "immediate bottom line." At times, this was very discouraging to me and to other members of the staff.

### Conflicting Objectives

One example of conflicting organizational objectives occurred at the stage of the project when sources for funding for feeder automation prototype system development were being investigated. One source of funds was offered to perform work very closely akin to work needed and planned within the R&D department. We (the R&D group in general and I specifically) were instructed to pursue this source of funds. When the pursuit brought fruit in the form of a request for proposal, the venture staff decided that there would be unnecessary burden placed on the staff of the venture to pursue this path. Support for the effort was withdrawn, and the potential funding was lost.

This is an example of R&D attempting to insure the future of the effort, while engineering is attempting to fight fires with the resources it has. There will always be conflict in situations of this nature and the conflict can be managed to yield productive behavior from both of the groups. I am sure that I am prejudiced in this instance, but I felt that more productive steps could have been taken.

### Customer Relations

The R&D group had a special place in the customer relations role. We were the "the pros from Dover." We were called in to participate in particularly difficult communications situations, or when the customer wanted to discuss the system in depth. We assisted customers in defining their own thinking about the potential application of the system.

### Vendor Relations

The UCS project developed several associated products which were used to implement the communication system. New products were being

developed which were designed to enhance the communication success rate and/or to reduce the cost of the system. The role of R&D in the vendor relations area was twofold. The first kind of relationship was during the development of new products. The vendor would propose a product to satisfy a need which we indicated we had, and we would try sample quantities of the product to determine its usefulness. The second kind of relationship developed when a vendor's product began to malfunction after application in the field.

When this occurred, R&D was asked to determine the cause of generic failures and recommend a solution, or solutions. R&D also dealt directly with the vendor to determine what course of action the vendor recommended. After the problem was identified, there was a period when the information gained from the understanding of the problem was added to the specification and testing process to avoid future problems of the same kind.

### Consequences

When the environment in which you work is uncertain, then the appropriate organizational position for which to strive is one of flexibility. Since the definition of feeder automation was rather vague, especially the part describing how the utility might use it, then the appropriate position for the UCS feeder automation system would be one of flexibility. Therefore, I designed a modular system which could be applied in any manner the utility cared to apply it. When ultimately installed in totality, it formed an integrated feeder automation system with the ability to perform its assigned function. This meant that the system could not evolve piece by piece as customers were found, but that the system had to be designed as a whole and disassembled into pieces which could not only perform their own functions in a stand-alone mode but which were capable of being integrated into a larger system without modification.

## SINCE THE INTERNSHIP

Since the internship, I have returned to the parent company of TESCO. I am currently assigned as supervising electrical engineer in the TUSI nuclear engineering group at Comanche Peak Steam Electric Station. One of the projects I am responsible for is the development and installation of a major minicomputer data acquisition and display system for the plant. I am responsible for the cost, schedule and the performance of the system and am designated as the project manager. The magnitude of the system development effort is essentially the same as that for the UCS venture. I had directly observed some of the most serious problems faced during system integration in the pursuit of performance, schedule and budget, and have sought to eliminate as many of them as possible. The experience at Rockwell is invaluable in this respect.

## CONCLUSION

Originally, I was skeptical about the worth of the internship for an individual who already had substantial experience. Dr. Porter, (Electrical Engineering Department, D.Engr. Program Advisor) among others, convinced me that I was mistaken. I embarked on the internship by having to inform TESCO that I would be working full time at Rockwell. Since I was on leave of absence for education, they were concerned that I did not "come back to work." If I had, I would have missed one of the most rewarding experiences of my life. Further, Texas Utilities would not have a computer system project manager who had "been there." I could not do as effective a job at what I am currently assigned to do if I had not had the internship experience.

In summary, the internship was designed to meet the requirements of the Doctor of Engineering requirements of Texas A&M University. It provided a broad experience for me covering difficult technical challenges in my area of expertise as well as management insight and participation.

I submit this report in satisfaction of the internship reporting requirement and for the benefit of those who may follow.

## REFERENCES

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**APPENDIX A**  
**MONTHLY INTERNSHIP REPORTS**

June 12, 1980

Dr. B. Don Russell  
Director  
Electronic Power Institute  
Department of Electrical Engineering  
Texas A&M University  
College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for  
the Month of May, 1980

Dear Dr. Russell:

Please accept this letter as my Internship Report for the month of May.

Since you already have my position description, let me just describe my position within the management hierarchy of this Rockwell venture. I am a Senior Systems Research & Development Specialist who functions primarily as a member of the staff of the Director of Research and Development, Mr. R. A. Arrington. There are five other program directors or managers who compose the senior management group of this venture. In all they are:

R. A. Arrington	Director of Research & Development
G. Bowling	Director of Product Engineering
P. G. Burgan	Systems Integration Manager
F. J. Kramer	Director of Business Planning & Operations
M. A. McDermott	Production Manager
J. R. Wittenburg	Director of Marketing

These individuals report to Mr. G. S. Rambo, Director of Utility Communications Systems (UCS).

The UCS group or venture as it is called, is a venture of the Municipal and Utilities Division of Rockwell International's General Industries Group. The venture was begun in approximately 1972 in an effort to satisfy a perceived market for distribution power line carrier equipment in the usage of electric energy. Some regulators even began to require that the utility make plans for implementing electric rates which would encourage what is called "off peak" use of electric energy thus reducing the amount of capital required for capacity construction and hence the cost of electricity to the customer.

There are several methods of implementing this kind of control which are beyond the scope of this letter. The method chosen for implementation by Rockwell International was using the distribution lines as a communications media. As you know, the distribution system is a particularly harsh environment from a communications standpoint. However, due to the expertise of Collins Radio engineers who have developed over the years techniques for communicating in harsh electromagnetic environments, Rockwell was successful in developing a power line carrier system which



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allowed the utility to communicate commands to customer interruption devices and receive meter readings from customer meters over the distribution system. The initial implementation of this system has been in the form of "load management" and "meter reading" equipment. That is bidirectional transponders installed at the customer's residence which are capable of basically two functions. Function Number 1 is accumulating and transmitting electric meter readings as well as readings from gas and water meters if they are properly interfaced. Function Number 2 is the interruption of customer loads when so instructed by the utility.

My primary function in this venture and group is to develop a strategy for implementing additional automation functions through use of power line carrier equipment. Some work had previously been done by others in this area but no formal proposals have been made to date.

My first assignment in this area was to develop a distribution automation voltage control proposal for implementation in cooperation with Wisconsin Public Service Corporation of Green Bay, Wisconsin (WPSC). WPSC had already implemented a load management system built by Rockwell International UCS. They desire to expand the use of their existing power line carrier system to control capacitor banks and step voltage regulators in a more closed loop fashion.

I was assigned a secondary task of assisting in the generation of specifications for a capacitor isolation inductor. These inductors are placed in series with capacitor banks normally employed by electric utilities to raise the zero sequence or positive sequence impedance to ground for our power line carrier signal at 5180 Hz. One of the test specifications required that the inductor be tested for inrush. The capacitor inrush phenomenon is described in the Westinghouse T&D Manual and is one which normally occurs each time a capacitor bank is switched. Therefore, anything which is placed in series with that capacitor bank would have to withstand numerous occurrences of the inrush phenomenon. I, therefore, calculated the expected amount of inrush current from different sizes of capacitor banks. The inrush current calculation was then used as a guide for testing the capacitor isolator.

Another secondary responsibility which I was assigned was that of designing a performance test for the radio controlled switch. The switch was a VHF FM receiver which used a switched capacitor filter and a microprocessor to detect various control tones and operate a relay which was in series with a customer water heater or air conditioner. These receivers were manufactured in prototype form for Rockwell by another manufacturer. Several of these receivers had previously been tried at Arkansas Power and Light and had failed to perform properly. I was asked to design a test which would determine whether or not the receivers met the sensitivity requirement of 50 microvolts in free space and also the adjacent frequency rejection specification. Using screen room

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and test equipment available at Collins Division of Rockwell International, I designed a test set up using calibrated antennas which would generate a calibrated RF field in and around radio receivers so that their performance could be measured. I was assisted by Mr. Tim Herron of UCS group who performed the actual test. His report is attached.

In summary, then this month I was assigned one primary duty: A proposal for distribution automation voltage control at WPSC. The completion date assigned was June 15. Second priority items were: assist in the generation of a capacitor isolation specification, and develop a testing system for the radio switch which was provided by another vender.

This completes the summary of my May activities in the Doctor of Engineering Internship.

Sincerely,



Tom J. Talley

TJT:dt

July 8, 1980

Dr. B. Don Russell  
Director  
Electronic Power Institute  
Department of Electrical Engineering  
Texas A&M University  
College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for  
the Month of June, 1980

Dear Dr. Russell:

Please accept this letter as my Doctor of Engineering Internship Report  
for the month of June, 1980.

My primary assignment for this month remained the Feeder Automation Proposal for Wisconsin Public Service Company (WPSC). The proposal was one which Rockwell had committed to make during earlier sessions with WPSC. Since the Load Management and Distribution Automation efforts are separate in nature, and tied through joint management at the senior level, it became apparent they wished to investigate the incremental cost and benefits of using their power line carrier system for other functions. The most obvious of those was Feeder Automation. Using background data provided by Mr. R. A. Arrington and others including engineering brochures on step regulator controllers, capacitor bank controllers, I designed down to the block diagram level, the hardware necessary to implement a Feeder Automation System as described by WPSC. The proposal included direct control from the dispatch office of two capacitor banks, one step voltage regulator and three remote voltage monitors. A copy of the proposal is attached. Cost estimates were made based on figures provided by engineering, production, field service, and our own estimate of research and development oversight expenses. The proposal was presented to WPSC at a meeting with R. A. Arrington, Bill Bourbonnais, Manager of Distribution Engineering, WPSC; other WPSC staff members and myself on the 12th of June, 1980, at WPSC's headquarters office in Green Bay, Wisconsin.

During that meeting a peripheral issue was discussed concerning the reliability of our power line carrier equipment. As previously mentioned in my report of May, 1980, capacitor isolation inductors are used by Rockwell UCS to provide high impedance zero sequence paths to ground for the power line carrier signal. The inductors are placed at the wye point of capacitor banks to ground of the WPSC system. During the rather severe cold weather of last winter, several of these epoxy encapsulated inductors exhibited cracks in the porcelain standoff insulators and the epoxy around the neck joining the insulator to the inductor body. WPSC was deeply concerned with the performance of these inductors after noting these cracks beginning. During the WPSC Feeder Automation Proposal meeting the question was asked what Rockwell intended to do to insure that no further cracking or failure of these devices would occur.

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Doctor of Engineering Internship for the Month of June

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As a result of that meeting Mr. Emil Rechsteiner, President of TDC Corporation, the manufacturer of the isolators for Rockwell, made an appointment to meet with Rockwell representatives, WPSC representatives and members of his staff in Green Bay to discuss the isolator problem. Mr. Arrington assigned me to attend the meeting along with representatives from Rockwell's production group. The meeting was held in Green Bay Wednesday, the 18th of June, 1980. Mr. Rechsteiner presented to the WPSC personnel the understanding of TDC as to how the units actually failed. It may be the difference in thermal expansion cohesion between the epoxy and porcelain standoff insulators induced stress in the epoxy which first cracked the porcelain thus allowing the epoxy to crack. Mr. Rechsteiner indicated of course that he would be happy to work with Rockwell in any way possible to alleviate any future problems that our customers might have with the insulator. Mr. Rechsteiner then scheduled a meeting with the venture manager, Greg Rambo, on Wednesday, the 25th of June, 1980, to present a proposal for modification of the capacitor isolators which would prevent any further cracking and customer dissatisfaction with the product, hence Rockwell Power Line Carrier Systems. Mr. Arrington suggested that I attend that meeting which would also be attended by Mr. Emil Rechsteiner, president of TDC Corporation; his national marketing manager; Mr. Greg Rambo, Venture Manager for UCS; and Mr. Mike McDermott, Production Manager for UCS. At the meeting on the 25th, Mr. Rechsteiner presented an all-epoxy design and stated that he would replace, at no cost, any of the isolators which had cracked in the main body of the isolator. He would not, however, replace isolators which had cracked merely around the neck. He presented an all-epoxy design for which he wanted a confirmed order and assistance in performing environmental test. I communicated the offer to Mr. R. A. Arrington. Mr. Arrington and the other managers in the UCS Venture determined our best course of action in the given situation was to pursue alternate suppliers of these devices.

Following the meeting in Green Bay with Mr. Emil Rechsteiner of TDC on the 18th of June, I remained in Green Bay for the usual Friday meeting between WPSC Load Management personnel and the Rockwell Field Service group to discuss the ongoing installation and operation of the Rockwell UCS Load Management System at WPSC.

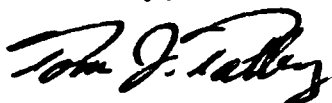
At Antigo Substation, there is apparently a phenomenon which Rockwell has not encountered previously with their communication system. It seems that an area or two which are remote from the substation have rather low signal levels on one phase but not on the other two. There have also been numerous radio interference complaints in that particular area. WPSC personnel were hoping that Rockwell would be able to find our communications problem and, thus, find their radio interference problem. We suggested, however, that finding radio interference might be easier to do.

Dr. B. Don Russell  
Doctor of Engineering Internship for the Month of June  
Page 3

Mr. John Arneth indicated that WPSC had acquired a radio interference finder built by Oak Industries. That particular interference finder is the end product of the prototype research which Dr. William Beasley of Texas A&M conducted during my senior year there in 1971. In fact, I built 16 prototypes of that system for the funding utilities around the state. The original prototype device was known as the EEIEM detector. WPSC said they had little experience with the unit but were pleased with its performance thus far and would be very anxious to have someone assist them who understood the mechanism involved. I, therefore, offered my services for the following week to assist Mr. Dale Mommaerts in a RFI study of the Antigo/Bryant area. Therefore, on the 26th of June, 1980, I proceeded again to Green Bay, Wisconsin, following the meeting at Pittsburgh where I assisted Mr. Dale Mommaerts in an RFI study of the Bryant area using the Oak Industries noise detector. Nine sites were worked with the help of line personnel Bryant-Antigo area. Seven noise source were found and corrected. Two were not corrected as they could not be located accurately.

In summary then, my primary objective remained the follow up of the WPSC Distribution Automation Proposal. Secondary objectives were to investigate the epoxy cracking in the capacitor isolator inductors provided by TDC Corporation. Another secondary function was to assist WPSC in identifying any radio noise sources in the Antigo area which could perhaps interfere with our power line communications signals.

Sincerely,



Tom J. Talley

TJT:dt

August 7, 1980

Dr. B. Don Russell  
Director  
Electronic Power Institute  
Department of Electrical Engineering  
Texas A&M University  
College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for  
the Month of July, 1980

Dear Dr. Russell:

Please accept this letter as my report of activities for the month of July, 1980, on my Doctor of Engineering Internship.

For the month of July my primary responsibility remained that of feeder automation. During July, however, the radio switch mentioned in my May Report was taken to Little Rock for further testing with Arkansas Power and Light.

As a result of meetings in Pittsburgh with Venture Manager, Greg Rambo, and in Dallas with Mr. R. A. Arrington it was determined that a new contractor should be found for providing the capacitor isolator inductors. In that light, a specification generated by Rockwell R&D was mailed by me to two potential contractors. One was Mr. Paul Leightner of Leightner Electronics in McKinney. The other was Mr. John Myers of Electromagnetic Industries, Inc., a division of Square D Company in Clearwater, Florida. Mr. Leightner indicated a willingness to provide the inductors given testing assistance by Rockwell. Mr. Myers of Electromagnetic Industries indicated that their engineering workload was such that they could not provide the inductor as we described. They did not feel it would be wise for them to attempt to retool to provide that product based on the time they estimated it would require. Therefore, they no bid the product. These results were reported to Mr. Arrington who reported them to our Production Manager, Mr. Mike McDermott, who assumed responsibility for communicating with other potential manufacturers of the isolators.

I might add that during this period I moved my household goods and family from Bryan to Dallas using two days' work, 7th and 8th of July.

During the week of July 14th through the 18th, I attended the Power Engineering Society meeting in Minneapolis, Minnesota. I assisted Mr. Dan Nordell, Programs Chairman, by being a monitor for one session each period. One session chairman who I worked for was Mr. Herb Klein of D.O.E. That relationship should prove fruitful to Rockwell International since Mr. Klein is Administrator of Programs such as distribution Automation Development and Power Line Carrier Communications System Development. Potential Rockwell customer, Mr. Dan Nordell, also appreciated my assistance. I also had a chance to visit with one of our

Dr. B. Don Russell

Doctor of Engineering Internship Report for the Month of July, 1980

Page 2

power line carrier users, Mr. Orville Hill of Pacific Gas and Electric. I discussed some of the aspects of applying power line carrier to distribution automation with him. As he is not only familiar with our power line carrier system but distribution automation proposals from other manufacturers, it was of great assistance to me to hear what he had to say.

The 21st of July, 1980, I went with Mr. Dick Brown to Little Rock, Arkansas, headquarters of Arkansas Power and Light to install six radio switches for test. These radio control switches first described in my May Report had been thoroughly tested as reported in the May Report. On arrival, Mr. Brown and I plugged the units in and tuned them to the appropriate frequencies on AP&L's Load Management Radio System. One unit failed to operate properly and the rest operated as specified. We left the units in Arkansas Power and Light's care for their evaluation. We returned the unit which failed to our Dallas office and then to the manufacturer which had supplied it to us for evaluation of its failure mode. It was later reported that a crystal had been loosened due to handling. It had been resoldered and the unit operated properly and the unit was returned to Rockwell in Dallas.

On the 30th of July, 1980, Mr. R. A. Arrington and I again proceeded to Green Bay, Wisconsin, to discuss any questions the Distribution Manager had concerning our Distribution Automation Proposal. It was felt that the proposal had been in their hands for nearly 45 days and that some action should be forthcoming. Several questions were discussed and as a result of that meeting the WPSC personnel had a much clearer understanding of the capabilities of the proposed Feeder Automation System.

This ends my report of activities for the month of July in the Doctor of Engineering Internship at Rockwell International.

Sincerely,



Tom J. Talley

TJT:dt

September 19, 1980

Dr. B. Don Russell  
Director  
Electronic Power Institute  
Department of Electrical Engineering  
Texas A&M University  
College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for  
the Month of August, 1980

Dear Dr. Russell:

Please accept this letter as my report of activities in the Doctor of Engineering Internship at Rockwell International for the month of August, 1980.

As before, my primary responsibility has been one of developing a feeder automation/distribution automation philosophy for Rockwell International UCS. In that light, during the previous month I had discussed with you and our national marketing manager at the Power Engineering Society Meeting the necessity of obtaining research and development funds from people like EPRI and DOE. Mr. Arrington, Mr. Wittenburg and yourself agreed that was probably the most reasonable course to pursue since EPRI was funded by the electric utility industry to do research of that nature and had done so in the past. Mr. Arrington suggested that he and I visit with Dr. Bill Blair, a Contract Administrator responsible for distribution automation and power line carrier system evaluation at EPRI. Mr. Arrington and others from Rockwell had previously visited Dr. Blair but had not pursued to any great extent obtaining funds from EPRI for research. On the 6th of August, 1980, I assisted Mr. Arrington in presenting a slide presentation to Dr. Blair at EPRI indicating Rockwell's communications capability and experience with power line carrier equipment. Dr. Blair seemed fairly impressed, and as a result of that meeting included Rockwell in the Request for Proposal List for an upcoming Distribution Noise Analysis and Recording Proposal. As a result of that meeting Mr. Arrington suggested that I develop a clear outline of what Rockwell International's Distribution Automation System must be and instructed that I was to present that outline at a meeting with the Venture Management at Dallas on the 14th of August, 1980. Based on that instruction, I proceeded to confer with the staff at Electric Power Institute at Texas A&M University to gain a full understanding of the implication of feeder automation systems as they apply to distribution automation. A summary report was generated outlining the functions required to perform present, near term and long term feeder automation functions. The software, hardware and interface requirements were also discussed. I generated an outline for the presentation on the 14th and the Director of the Electric Power Institute, Dr. B. Don Russell, generated some verbiage which described in a little more detail the functions which were included in the outline. As a result of my presentation of distribution automation system plan on the 14th of August, 1980, Venture



Dr. B. Don Russell

Doctor of Engineering Internship Report of Tom J. Talley  
for the Month of August, 1980

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Management required of the Director of Marketing and the Director of Research and Development that they make a presentation on the 22nd of September which would include an estimate of the effort required to accomplish the proposed plan and cost of that effort as well as resources available and which must be required to accomplish those goals. The Marketing Director was also requested to provide an estimate of the sales or detriment of sales if the distribution automation functions were not provided. A reasonable time frame for implementation of distribution automation systems was also requested.

It was determined by the National Marketing Manager, Research and Development Director, and the Venture Manager that one of the best ways to reach an understanding of how the utility industry views distribution automation would be to gather knowledgeable utility representatives from across the country in a seminar type meeting. In an open forum, representatives would be able to determine:

- a. Whether or not distribution automation as viewed by Rockwell International was necessary and sufficient.
- b. Whether or not the implementation of the proposed plan of Rockwell International would preclude implementation of any future desired distribution automation functions as seen by the industry representatives.

It was felt by all members present that an independent agent would probably be best to moderate the program and an attempt by Rockwell to control the program would bias the results and not give meaningful information as a result. The Director of Electric Power Institute, Dr. B. Don Russell, was contacted and requested to assist Rockwell in this endeavor. An outline of the meeting was generated on the 26th of August, 1980, by Dr. Russell, Mr. Arrington and Tom Talley. The meeting was to be carried on in a discussion seminar style so that at the close of the meeting those individuals present would all feel that they had contributed to Rockwell International's policy and plan of distribution automation equipment implementation. The meeting was tentatively scheduled to be conducted on September 2nd and 3rd at Rockwell International's Dallas Presentation Center. The list of those individuals invited from across the country at the meeting itinerary is attached.

I felt that I had accomplished a major objective of mine which was to increase Rockwell International's input from the utility industry concerning their distribution automation systems. It was, and still is, my feeling that Rockwell International is not as closely in touch with the industry as they might believe. In an effort to correct that perceived deficiency, I felt that any utility interaction with Rockwell would be of great benefit in planning and implementing systems for sale to that

Dr. B. Don Russell  
Doctor of Engineering Internship Report of Tom J. Talley  
for the Month of August, 1980  
Page 3

industry. It is a Rockwell policy at this point to attempt to make ventures profitmaking as quickly as possible. That is, it is a tendency of management to want immature products sold for return on investment so that future development in those products can be paid for by those who buy the first generations. I feel that Rockwell does not fully understand the utility industry philosophy of purchasing. I have made every attempt to communicate the inherent conservatism of the industry to Rockwell management but seem to be unable to do so. I, therefore, feel that since I am unable to communicate that conservatism to management, that I must place management in the position of having to listen to that conservative view expressed by utility representatives themselves. Therefore, I was able to get management's agreement that it was necessary to have a meeting of the kind being held next month so they could sort out the real utility philosophy for themselves.

In summary, then, my August activities include assisting in a presentation at EPRI on distribution automation and Rockwell's capability in power line carrier communications systems. Presentation of distribution automation implementation requirements to Rockwell UCS management. As a result of that presentation, Rockwell management instructed me to conduct a meeting of utility representative to get their views on distribution automation and return with a plan of implementing the distribution automation system for Rockwell by the 22nd of September.

Sincerely,



Tom J. Talley

Attachments

Dr. B. Don Russell  
Director  
Electronic Power Institute  
Department of Electrical Engineering  
Texas A&M University  
College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for  
the Month of September, 1980

Dear Dr. Russell:

Please accept this letter as my Doctor of Engineering Internship Report  
for the month of August, 1980 at Rockwell International-UCS, Dallas.

The month began with the assembly of several utility representatives  
from across the country to discuss feeder automation at Rockwell's  
Dallas facility. I coordinated the arrangements and commitment for par-  
ticipation of the various utilities and individuals concerned. In con-  
junction Mr. R. A. Arrington and Consultant, Dr. B. Don Russell, a pro-  
gram for presentation and activities was prepared which would achieve  
the objective of the program.

Nineteen utility and UCS representatives to the program participated in  
a two-day meeting which covered primarily the functions of feeder  
automation and how those functions should be implemented from the  
utility point of view. As might be expected, functions fell along  
reasonable lines, but the method of implementation was different  
depending on the utility involved. From that we determined, after some  
lengthy discussions, that a modular concept was an important part of any  
successful feeder automation system. That is, each of the modules  
separately can perform valuable functions for the utilities and that  
each module is as independent from every other modules as possible so  
that the system when assembled can be assembled with any number of  
modules and functions to satisfy a particular utility's needs but can  
also be integrated to form a completely integrated system serving all  
functions recognized by the utilities.

During the month of September I also prepared a detailed report on the  
activities which were accomplished by me in June of this year. The re-  
port outlined the difficulties involved in tracking RFI sources and in  
asserting that those sources may in fact have any impact on power line  
carrier systems. I suggested in the RFI report to Wisconsin Public  
Service Corporation that upgrading 7200 volt distribution systems 25 KV  
class involved more than simply buying 25 KV insulators. That other  
utilities had experienced RFI problems unless the hardware on the pole  
was mechanically loaded by spring clamps and the like. My experience at  
Texas Electric Service Company led me to believe that this is true, and  
reading periodicals of the industry confirms that belief. I made sug-  
gestions and recommendations to WPSC that they at least involve them-  
selves in an RFI minimization program in the area of Antigo Substation

Dr. B. Don Russell  
Doctor of Engineering Internship Report of Tom J. Talley  
for the Month of September, 1980  
Page 2

Substation in which we investigated. Description of that investigation is contained in my letter of June 1980.

As mentioned in my letter of August 1980, Mr. R. A. Arrington and I went to EPRI August 6th. We discussed briefly with Dr. Bill Blair the possibility of Rockwell International becoming involved in EPRI power line communications. Dr. Blair, as a result of that meeting, forwarded a request for proposal to Rockwell International. The proposal dealt primarily with identifying noise sources on distribution lines, categorizing the noises, determining the source and making recommendations for reduction of noises on the distribution lines. Dr. Blair's view of the proposed project was that it would be a one to two year project minimum, perhaps budgeted on the order of a half million dollars. Mr. Arrington and I prepared a presentation which I mentioned the 14th of August which outlined the necessity of having an ongoing relationship with the Electric Power Research Institute. The request for proposal required a response from Rockwell International on October 30, 1980. Mr. Arrington and I both made strong pleas to the senior management of the organization but were unsuccessful in our attempts to convince the senior marketing and senior venture management that an ongoing relationship with EPRI would be of benefit to the venture. As a result on September 30, we informed Dr. Blair that we would be unable to bid on the noise study request of proposal.

In addition to the above list of activities, work continues on the analysis of failures of the radio switch, and the capacitor isolator inductor.

I have attached a list of attendees of the Feeder Automation Conference on September 2 and 3 as well as a summary of the meeting notes.

In summary, my activities for the month of September have included conducting of a feeder automation conference including arrangements for the individuals attending the conference, recruiting attendees, planning the program for the conference, and assisting in the execution of the program. Several meetings with venture staff occurred during September, during which R. A. Arrington and I attempted to persuade venture staff that activities involving EPRI would be worthwhile for the venture. These activities were unsuccessful.

I prepared a RFI report for Wisconsin Public Service Corporation. I briefed a new marketing individual on power line carrier systems and some of the technical aspects involved in that science.

Dr. B. Don Russell  
Doctor of Engineering Internship Report of Tom J. Talley  
for the Month of September, 1980  
Page 3

I hope that you find this letter suitable as my Doctor of Engineering Internship Report for the month of September 1980.

Sincerely,

A handwritten signature in cursive script, appearing to read "Tom J. Talley".

Tom J. Talley

TJT:dt

Dr. B. Don Russell  
 Director  
 Electronic Power Institute  
 Department of Electrical Engineering  
 Texas A&M University  
 College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for the Month of October, 1980

Dear Dr. Russell:

Please accept this letter as my Doctor of Engineering Internship Report for the month of October 1980.

Activities during October broke into three primary areas.

Area 1 was an investigation of the effects of capacitor isolator inductance resonating on power line carrier system. Area 2 was a continuation of feeder automation plans as developed at the meeting of September 2 and 3 and over the period preceding that by Rockwell International. Area 3 involved a three day project management seminar conducted by American Management Association to which I was sent by the company.

Inductant Resonance: Since the power line may be viewed as a transmission line for all practical purposes, the effects of any device connected to the transmission line should be investigated from the standpoint of standing wave effects and the like. For a period of weeks it had been wondered what the effects would be of resonating capacitor isolator inductors which are used to increase the impedance to ground of the power line carrier signal. After some discussions among the R&D personnel, it was decided that there would be several benefits to resonating the isolators. These benefits would include:

- A. Increasing by factor of  $Q$  the impedance of the inductor at the carrier frequency.
- B. That the impedance to ground at a capacitor bank would no longer be reactive but would appear resistive at a value of  $X$ , the reactance of the inductor previous to resonating, times  $Q$  (the quality of the circuit). The  $Q$  was measured in the lab beyond the order of 7, therefore, the impedance to ground of the signal would be raised by 7 times its current value.
- C. The existing value of the inductor reduces an impedance to ground at 5180 Hz of approximately 52 ohms.  $Q$  equaling 7 would produce an impedance to ground at capacitor banks of 7 times the previous impedance or approximately 350 ohms.

Dr. B. Don Russell  
Doctor of Engineering Internship Report of Tom J. Talley  
for the Month of October, 1980  
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- D. This value of 350 ohms more nearly matches the characteristic impedance of the distribution line as viewed as a transmission line in a classical sense. Transmission line thus being duly matched by its characteristic impedance would be flatter from a standing point of view thus reducing the probability of there being areas of signal nulls. For these and other reasons it was decided that a continuation of the effort to resonate capacitor isolators would be necessary. All this work was done in close conjunction with Mr. W. C. Perkins, a 25 year Collins Radio Communications expert. There was a four day intensive period of brain storming followed by application critique which led to a prototype specification for resonating capacitor isolator inductors while protecting the capacitors from transients.

This was one of several occasions in my career at various companies where I have observed the team concept of solving problems as taken in EG 105 and 106 and is the most effective. There seems to be generated some synergism when a positive attitude is taken by highly skilled technical personnel toward the solution of a problem. Obstacles are met with understanding and not frustration and surmounted with the application of expertise and experience with a rapidity which can hardly be described. I heartily endorse this type problem solving activity.

Feeder Automation Activity: Rockwell International was requested to respond to a request for proposal from Duke Power Company. The request included several paragraphs of comments on feeder automation activities at Rockwell International. I was requested to draft these paragraphs which I did (copies attached). I described in this draft concepts which Rockwell International had developed as a result of the Feeder Automation Conference of September 1980. The concepts included modular system application, overall system integrability, maximum system flexibility and application, as well as communications reliability.

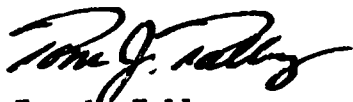
Project Management Seminar: Rockwell International sent me and six other engineers to a project management seminar conducted by American Management Associates. The management seminar was aimed at the effective management of engineering projects.

In summary, my October activities included intensive technical research and development activity on capacitor isolator inductor resonating, a continuing feeder automation activity which included preparing a draft for response to Duke Power's RFP. A three day project management seminar was also attended.

Dr. B. Don Russell  
Doctor of Engineering Internship Report of Tom J. Talley  
for the Month of October, 1980  
Page 3

I hope that this letter is suitable for my October Doctor of Engineering  
Project Report 1980.

Sincerely,

A handwritten signature in cursive script, appearing to read "Tom J. Talley".

Tom J. Talley

TJT:dt

Attachment



Dr. B. Don Russell  
Director  
Electronic Power Institute  
Department of Electrical Engineering  
Texas A&M University  
College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for  
the Month of November, 1980

Dear Dr. Russell:

Please accept this letter as my Doctor of Engineering Internship Report  
for the month of November 1980.

The month of November was almost entirely taken up with the analysis of materials problems on the capacitor isolator inductor. Capacitor Isolator Inductor is an integral part of the power line communications system on which I work. It is discussed in my June letter of 1980, our current supplier of capacitor isolators was having a materials problem which could not be overcome easily. The environmental test report which was attached earlier detailed the mode of that failure. During the intervening period from July to November I had been working with Mr. Paul Leightner, President of Leightner Electronics, McKinney, Texas, to develop the new inductor which would serve as a capacitor isolator. Mr. Leightner had a certain amount of experience in the area of high voltage power supplies and epoxy casting. These devices were to withstand various environmental constraints. Based on his experience we instructed him to build a prototype to meet our specifications. I then wrote a test specification for environmental testing and selection process which included modifications of ANSI Standards and Military Sampling Standards to accommodate our requirements. I then supervised the accomplishment of the environmental test during which it was proved beyond a shadow of doubt that our previous supplier had a materials problem at a significant statistical level and that the inductors furnished by Mr. Leightner under my supervision were borderline of having a materials problem. Two inductors were produced by Leightner Electronics, one of which passed the environmental cycling test described in the memorandum attached, the other which did not. The one which did pass was used as a guide to build four other devices. Arrangements were made with McGraw Edison High Voltage Test Laboratories to test these devices in December 1980. Therefore, an electrical specification and test plan were written by me prior to that period. In addition I wrote an environmental report on the performance of the TDC isolators, a copy of which is attached.

In summary, my month was almost entirely consumed by activities relating to the capacitor isolator inductors and the materials problems.

Dr. B. Don Russell  
Doctor of Engineering Internship Report of Tom J. Talley  
for the Month of November, 1980  
Page 2

I hope you find this letter acceptable as my report of activities for my  
Doctor of Engineering Internship for the period of November 1980.

Sincerely,



Tom J. Talley

TJT:dt

Attachments

Dr. B. Don Russell  
Director  
Electronic Power Institute  
Department of Electrical Engineering  
Texas A&M University  
College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for the Month of December, 1980

Dear Dr. Russell:

I hope you find this letter acceptable as my Doctor of Engineering Internship Report for the month of December 1980.

The four prototype inductors mentioned in my November 1980 monthly report were taken to McGraw Edison Test Laboratories in Franksville, Wisconsin, and tested by the test plan attached. The inductor passed the I<sup>2</sup>T Test with flying colors. The epoxy tended to hold the inductor together during periods of high currents so that the inductor was very strong compared to an oil emersed device. The I<sup>2</sup>T achieved by the device was on the order of  $27 \times 10^6$  Amp<sup>2</sup> seconds. The turn to turn test as described in the IEEE Terminology and Test Requirements for Neutral Grounding Devices was conducted as shown in the test procedure, Circuit No. 1 and No. 2. In each case, the sample failed after some 100 to 200 capacitor discharges into the inductor. These failures were on the order of 40 kilovolts. As the result of these electrical failures, it was decided that a more careful design process had to be instituted over which R&D had a great deal of control. Neither Mr. Leightner nor anyone else whom we contacted had experience dealing with epoxy castings at the voltage test levels that we were attempting to match. R. A. Arrington and I began an intensive survey of material suppliers as well as bringing on board mechanical stress analysis expert from Collins Radio. The mechanical stress analysis was performed to indicate whether or not the epoxy selected for the final process would be sufficiently strong to withstand the differences in coefficient of expansion of the iron inductor core and the fiberglass epoxy coating surrounding that core.

In addition, December marks the month of the beginning of preparation of the Strategic Business Plan for the venture. I was invited to cooperate closely with the Director of Research and Development in preparation of his Strategic Business Plan. A copy of this Strategic Business Plan for 1982 through 1986 is attached. My participation included the determination of critical items in the research and development activity which should be accomplished. I assessed the time frame in which these items might be accomplished, wrote the explanation of these items, and presented preliminary views of the Strategic Business Plan to the Venture Director of Engineering, Mr. J. W. Smart; and with Mr. Smart and Mr. Arrington reviewed the SBP with the financial group after costs had been assigned to each SBP item.

Dr. B. Don Russell

Doctor of Engineering Internship Report for Tom J. Talley

for the month of December, 1980

Page 2

The materials analysis indicated that pressures in the epoxy during hot/cold transitions might be as high as 3,000 PSI. The epoxy finally chosen for use in the inductor was Emerson-Cumings product Stycast 2850 FP Blue which had a tensile strength on the order of 8,000 PSI. Mr. Maartin Vet, materials expert from Collins Radio, suggested that we should verify this tensile strength by pouring a small casting of this material, milling it to a prescribed size and then pulling the casting apart, thus measuring the modulus elasticity and plastic and elastic limits. The castings were designed and samples of the epoxy obtained at the close of the month. Testing was expected to proceed on the 5th of January when Rockwell returns to work from the Christmas Holidays.

In summary, my activities have been divided between strategic business plan for the venture and continuing design of the capacitor isolator inductor.

I hope you find this letter suitable as my monthly report for the month of December 1980 for my Doctor of Engineering Internship with Rockwell International.

Sincerely,

A handwritten signature in black ink, appearing to read "Tom J. Talley", written in a cursive style.

Tom J. Talley

Dr. B. Don Russell  
Director  
Electronic Power Institute  
Department of Electrical Engineering  
Texas A&M University  
College Station, Texas 77843

Reference: Doctor of Engineering Internship Report of Tom J. Talley for the Month of January, 1981

Dear Dr. Russell:

Please accept this letter as my Doctor of Engineering Internship Report for the month of January, 1981.

This month completes my nine month internship with Rockwell International from May, 1980, through January, 1981.

My principal effort this month was placed on the completion of the final design for the capacitor isolator inductor. This included directing Hy Pot testing of interim construction devices, verify the insulation materials and epoxy electrical strength. Later in the month environmental testing was conducted to insure that the epoxy used would stand up to the severe environmental constraints required by electric utilities. As of this writing, work is still required in modifying the design to accommodate the differential coefficient of thermal expansion between the steel and the epoxy as further cracking has been experienced in the epoxy. Alternative designs have been developed and suppliers have been contacted and sent drawings and specifications for the device.

During the past month we have incorporated several insulating materials and insulating schemes in the inductor design which should overcome the turn-to-turn voltage failure which we experienced earlier. Encapsulating all these materials in epoxy, however, still remains a problem due to thermal expansion coefficient differences with the iron core. Several moderators have been suggested. One such moderator suggested by Thermoset Plastic Incorporated is the use of electrically inert sand to modify the coefficient thermal expansion of epoxy to more nearly match that of the steel. Emerson Cumings Incorporated sells a glass bubble nitrogen filled filler which is used for much the same purpose but with a little less aptitude for corona propagation. These materials as well as conformal epoxy coatings covered by Butyl rubber injection molding techniques have also been studied. It is my opinion that some compromise between these techniques will result in a suitable product.

I recommend that a conformal coating of Emerson Cumings product Stycast 2850FT Blue used with Catalyst Stycast 1264 Part B be used to develop the conformal coating around the inductor and the insulating material shown in the attached layout diagram. Following the conformal coating stage of production of the inductors, the coils should then be attached to the inductor core and the entire assembly cast by an injection molding process of Butyl rubber. It is my feeling based on our experience

Dr. B. Don Russell  
Internship Report for Month of January  
Page 2

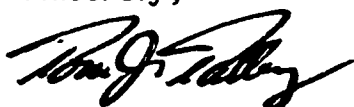
with epoxies of various kinds of constraints that no all epoxy device will be of suitable construction to withstand the environmental constraints we place on the product. Butyl rubber on the other hand, being a softer, more resilient material, may very well withstand the significant expansions and contractions induced in the core by temperature variations. Butyl rubber also has reasonable voltage characteristics.

I further found and recommended two testing standards be adopted in the specifications for the capacitor isolator inductor. The Environmental Test Standard recommended was ANSI Standard 186-11E which is the Thermal Shock in Air Environmental Test. An electrical Test set out in IEEE committee recommendations on neutral grounding devices was also recommended for adoption. Both these specifications are more severe than the specification currently adopted by Rockwell, but better represent the feeder requirements of the industry.

In summary then, my activities this month were almost exclusively in continuation of the development of the capacitor isolator inductor product. They involved both electrical and environmental specification determination. Materials were selected and tested piece by piece to determine their voltage breakdown levels and their overall effect on the product.

I hope you find this letter satisfactory as my Report for Doctor of Engineering Internship for the month of January, 1981.

Sincerely,

A handwritten signature in cursive script, appearing to read "Tom J. Talley".

Tom J. Talley

**APPENDIX B****WISCONSIN PUBLIC SERVICE COMPANY  
FEEDER AUTOMATION PROPOSAL**

A PROPOSAL

ANTIGO SUBSTATION

P H A S E I

VOLTAGE/VAR MONITORING & CONTROL

JULY 30, 1980

A JOINT FEEDER AUTOMATION SYSTEM

DEVELOPMENT PROJECT

WISCONSIN PUBLIC SERVICE CORPORATION

AND

ROCKWELL INTERNATIONAL

UTILITY COMMUNICATIONS SYSTEMS



## I. INTRODUCTION

### FEEDER AUTOMATION AT WPSC

This document proposes a systematic plan for the development and implementation of a Feeder Automation System. Wisconsin Public Service Corporation (WPSC) and Rockwell International Utility Communications Systems (UCS) have committed to the development and evaluation of this new and powerful evolution in power system control. By hosting this development on their system, WPSC not only gains direct control of the future development of Distribution Automation System, but WPSC will also gain the experience necessary to evaluate the worth of much larger future projects.

Phase I of this two-phase project calls for Rockwell to provide a method of direct feeder voltage control and monitoring to WPSC.

Phase II will expand the Distribution Automation System to include load restoration, redistribution and fault isolation.

### PROPOSAL ORGANIZATION

This proposal is organized to logically present the fundamental modifications in equipment and philosophy necessary to successfully implement Phase I of Feeder Automation Project. Rockwell UCS power line communications equipment forms a solid basis on which to build a Distribution Automation System. WPSC's experience with the Power Line Carrier will facilitate an orderly evolution to the equipment of broader functional capability required to perform the distribution automation function.

The following is an outline of the proposal organization and the topics discussed in each section:

- I. Introduction: Examines the value of distribution automation systems. Describes the organization of this proposal. Discusses the exchange of knowledge and experience necessary to successfully implement a Distribution Automation System.
- II. System Operation: Discusses the operator interface of distribution automation, evolution of SCADA and the two phases of this Feeder Automation Proposal. Power Factor Correction Capacitors, and voltage regulators are discussed in conjunction with the functional character of transponders used to monitor and control them.

III. System Control: Explains what the system is intended to do from the operator's point of view.

IV. Hardware Description: Outlines the equipment designed to implement the feeder automation functions and how it has evolved from "off-the-shelf" Rockwell Power Line Communications equipment.

V. Expected Benefits of Joint Development: Explains the advantages to both WPSC and Rockwell of this small scale Feeder Automation System.

VI. WPSC Support: Covers participation of WPSC in support of the Feeder Automation Project.

## VII. Schedule

### JOINT DEVELOPMENT

A joint project of this nature requires a willingness of the participants to share their respective skills. Rockwell brings decades of communications and high technology engineering and management experience to the proposed project. WPSC will provide years of experience in distribution operation practices. The combination of these carefully acquired skills will yield a highly capable, reliable, and useful Distribution Automation System that will benefit WPSC, Rockwell and the entire utility industry.

### SYSTEM OVERVIEW

The use of Supervisory Control and Data Acquisition Systems has become much more prevalent in distribution systems. Their utility and cost effectiveness has been carefully weighed by the electric utility industry. Day-to-day operation of larger, more complex distribution systems with fewer and fewer people, requires dependable remote control over the power system such as that provided by SCADA systems. SCADA usually ends at the substation load operating bus. A natural evolution in the management of power systems is the extension of control and monitoring of power systems parameters beyond the substation bus, even to the customer meters.

The extension of power line communications technology to the automated control of distribution system parameters becomes simply a logical evolutionary step. Phase I of this two-phase project calls for Rockwell to apply its expertise in communications and control to the automation of a relatively long feeder from the

Antigo Substation of WPSC. The successful management of the feeder will require the control of two capacitor banks and a voltage regulator. Remote voltage transponders will furnish additional data for the operator and automation system to use in managing distribution system operation.

Distribution automation brings about a subtle change in dispatch philosophy. Since the automation system can monitor voltages, currents, and other parameters at points along the feeder, control of system voltage by direct measurement becomes possible. The automation system is capable of gathering voltage data from the entire length of the feeder. The system can analyze the data and determine what steps, if any, are required to correct the feeder voltage. Power factor correction capacitors and voltage regulation can be controlled and their actions verified. By using an interface with the substation SCADA, the automation system also has the capability of monitoring all generally available bus parameters.

All this data gathering and analysis capability will enhance the utilities abilities to run its distribution system. WPSC will be able to use the data gathered to assist in sizing and locating capacitor banks, voltage regulators, and additional load management systems. With real-time remote monitoring capabilities, WPSC will be able to safely evaluate different dispatch philosophies while observing their cost effectiveness.

## II. SYSTEM OPERATION

The Phase I Feeder Automation System will allow the operator to automatically control and monitor voltage along a feeder at Antigo Substation. Figure 1 is a schematic representation of Phase I of the WPSC/Rockwell Feeder Automation Project. The operator terminal is either a video terminal or "hard copy" terminal which communicates by phone line to the Substation Terminal at Antigo Substation. The Substation Terminal relays commands to the three type of transponders located along the feeder. The two Type 1 capacitor controllers shown as T1A and T1B are collocated with the VST controls currently in place. The three Type 2 voltage sensors shown as T2A, B and C are located beyond the voltage regulator to measure voltages at remote points along the line. The Type 3 voltage regulator transponder (T3) will be placed near the Load Drop Compensator (LDC) at the regulator site.

The operator will be able to treat the capacitors and voltage regulators on the feeder much like additional SCADA points. The evolution of direct control of remote distribution system parameters will be provided by extensions of new functions from Rockwell's existing power line communications system. Voltage control will be supplemented by load restoration, redistribution and fault isolation functions provided by implementation of Phase II of this development project.

The system operation will be nearly transparent to the operator. The Central Communications Computer software can be modified to display the feeder parameters and allow direct control of the system by keyboard command from the operator position. The operator commands will be transmitted by phone line to the System Terminal (ST) located at Antigo Substation. The ST will interpret the commands and send the appropriate commands to the transponders located along the feeder.

The System Terminal (ST) will be a more intelligent device than its predecessor, the Substation Controller (SC). The ST will communicate with, and supervise, the operation of the Feeder Automation System Transponder (FAST) as it performs the voltage control algorithms.

The ST will be capable of the following operations:

- (1) The ST will store feeder parameters at the substation by monitoring the Supervisory Control and Data Acquisition System parameters. 30 KW, KVARs, and volts (120 V nominal) will be measured. These parameters, in addition to those reported at the remote transponder location, will be forwarded periodically to the operator terminal for display at the operator position.

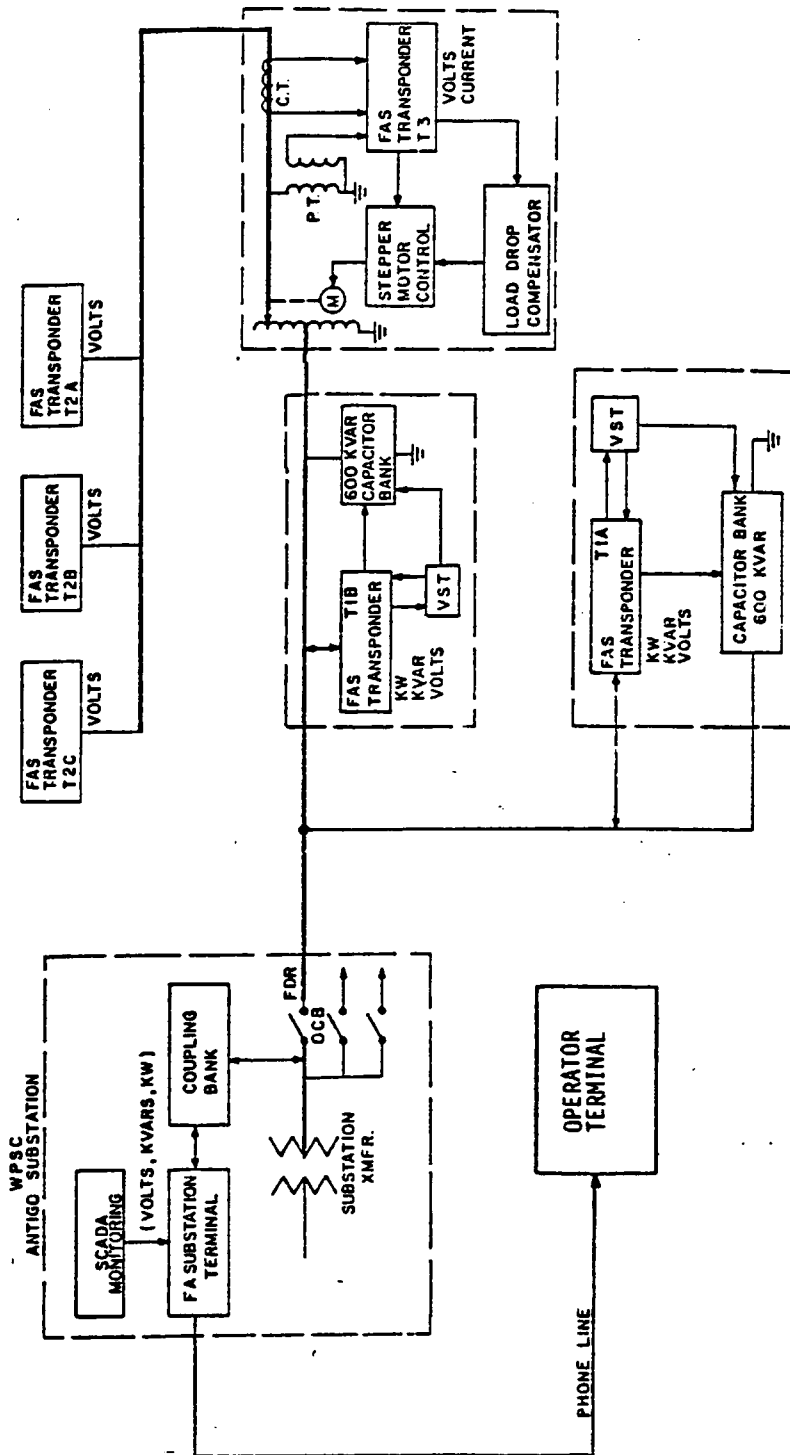


FIGURE 1 PHASE I  
HPSC/ROCKWELL FEEDER AUTOMATION SYSTEM

- (2) The ST can control the feeder to any nominal voltage specified by the operator. This function may be used by the operator to implement energy conservation by voltage reduction.
- (3) The ST can command the trip/close of either of the controlled capacitor banks, and raise/lower of the voltage regulator. (Provided the controllers on these devices are in the auto position.)
- (4) The ST can supervise the nominal voltage tracking algorithms performed by the capacitor control transponder and the voltage regulator transponder.
- (5) The ST can place control FASTS in any one of 3 modes, Direct, Automatic, or Monitor. The ST can also change the mode of operation of any or all transponders independently.

All equipment modification made necessary by the installation of the Rockwell Feeder Automation System will preserve the integrity of the manual mode select switch position on the capacitor and Voltage Regulator Controllers. This will allow the capacitor banks to be operated locally without fear of an automatic operation. The Voltage Regulator is protected in the same manner allowing only local control except when the transfer switch is in the automatic position.

#### POWER FACTOR CAPACITOR CONTROL

Control of Power Factor Correction Capacitors is performed by Sangamo's VS controller. This voltage control is implemented as shown in Figure 2. If voltage exceeds a set point, the bank will be removed from the line.

When the voltage decreases, the meter point makes contact with the low set point. This energizes a relay causing the capacitor switches to close. Conversely, as the voltage increases the meter pointer makes contact with the upper set point. This de-energizes the relay causing the capacitor switches to open.

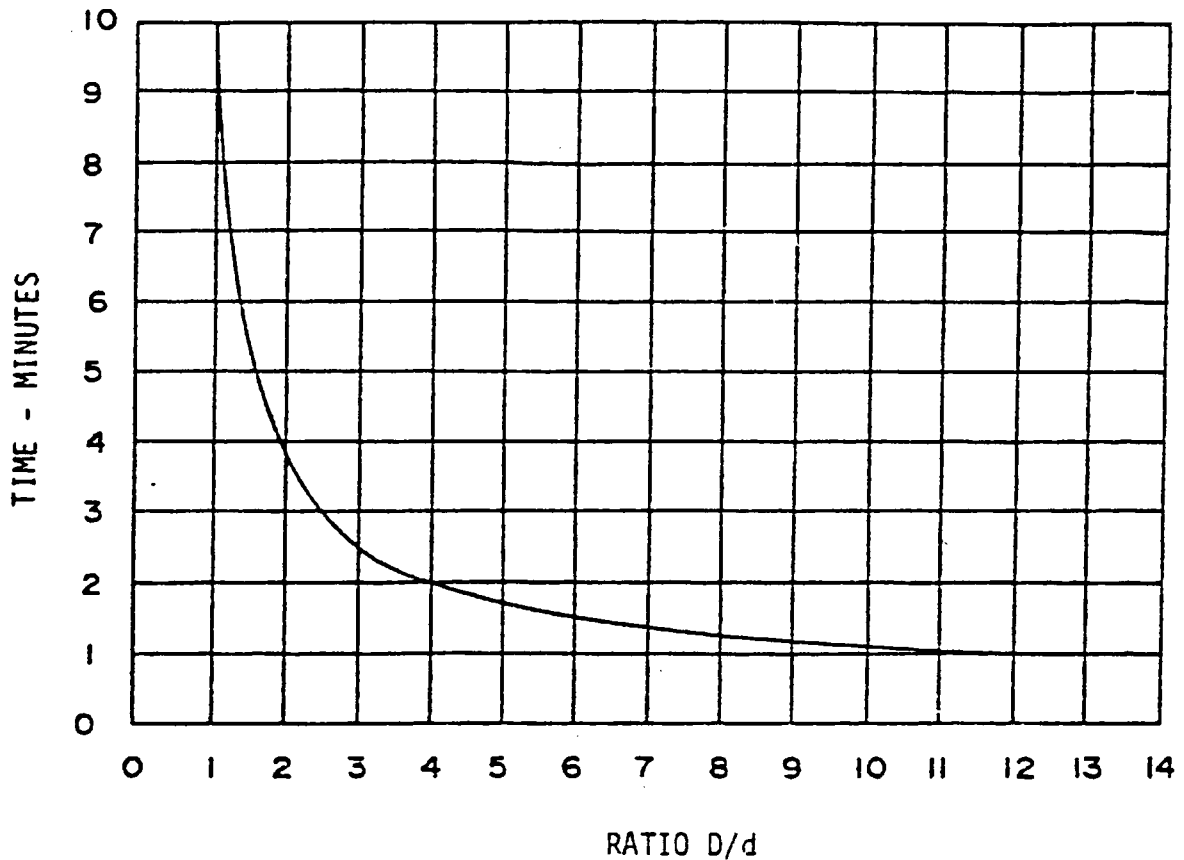
Figure 3 shows the inverse time characteristic curve of the controller. This characteristic prevents the bank from operating too rapidly. This delay is accomplished by the thermal time constant of the meter.

One sophistication of this controller is to add time sensitivity bias. This is known as VST control. A clock is added to the controller to increase the sensitivity during selected periods of the day when a set temperature is exceeded.

#### MODIFICATION FOR AUTOMATED CONTROL

The FAST interface provides a set of control relays which control the capacitor switches when the VST controller is in the auto mode.





INVERSE TIME CHARACTERISTICS - TYPE VS LINCOLNTROL

Time vs  $D/d$

$D$  = Total volts change = New volts minus pointer indication.

$d$  = Volts change to operate contact = Contact setting minus pointer indication.

EXAMPLE 1. Meter indicates 110 volts  
 New Volts 125 volts  
 Upper contact setting 115 volts  

$$\frac{D}{d} = \frac{125-110}{115-110} = \frac{15}{5} = 3$$

EXAMPLE 2. Meter indicates 125 volts  
 New Volts 113 volts  
 Lower contact setting 123 volts  

$$\frac{D}{d} = \frac{113-125}{123-125} = \frac{-12}{-2} = 6$$
  
 $t$  (from curve) = 1.5 Min.

FIGURE 3 INVERSE TIME CURVE OF VST CONTROLLER



The capacitor local control algorithm is fairly simple. If the bank is off, and voltage falls below the lower limit for longer than "time delay", and the VARS at the bank and substation are lagging, then the bank switches are closed.

If the bank is on line, and the volts rise above the upper limit for longer than "time delay", the bank is removed from the line. Also, if VARS at the substation or at the bank go leading, the bank is removed from service.

In addition, the ST uses the capacitor banks to raise the input voltage to the voltage regulator if need be. Should the regulator hit the highest step available, it notifies the ST at the next interrogation. The ST checks the VARS at the substation and capacitor banks, and if they are lagging and near nominal in voltage, then the ST closes a bank. This raises the input voltage to the regulator.

The recommended modification for remote control is to supply 120 V provided from the auto/manual switch to directly control the close/open switch relay. Provision for incrementing the operation counter is incorporated in the modification. This modification provides direct response to operator commands. During maintenance with the auto/manual switch in the manual mode, power is removed from the controller and the capacitor bank can be operated only manually.

## The PFC Capacitor Control Transponder (T1A & T1B)

The hardware used for capacitor control is shown schematically in Figure 4. This hardware consists of a standard Rockwell power line communications transponder and a Data Acquisition Terminal. The Substation Terminal communicates with the transponder to command the voltage set point and bandwidth. Time delays are specified by the Substation Terminal also. The data acquisition module converts voltage, KW, and KVARs to digital values.

The data acquisition module and the software to operate it are two design tasks to be accomplished during Phase I of this Automation Project. The expansion of the transponder software to include control of the data acquisition module and interpretation of the data is another design task for this project. This software will allow automated capacitor bank control of set point, bandwidth and delay. The inverse D/d characteristic will be incorporated. A suitable smoothing algorithm will be used to assure timely operation of the capacitor bank.

The transponder employed for Power Factor Capacitor control is virtually unchanged except for its additional data gathering capability. The PT and CT provide voltage and current inputs to the volt, KW and KVAR transducers. Standard 120 V, 5a inputs will be used to generate 0-1ma currents through appropriate input voltage levels to the Analog to Digital Converter. When the transponder desires a sample of the value of any of the parameters, it commands the multiplexer to select the appropriate transducer output. The 8 bit A/D converter loads the digital equivalent of the analog signal into the transponder.

## OPERATION VERIFICATION

The relay for control of the capacitor bank will have monitor contacts for verification of the relay operation. Additionally, the transponder will verify the operation of the capacitor bank by measuring volts, KW and KVARs immediately before and after commanding the relay operation. The differences in these parameters will verify the switch operation.

The resultant voltage and VAR change should be measurable at the substation through pre and post operation SCADA monitored values. This monitoring will allow distribution operations to make recommendations to engineering based on the effectiveness of the capacitor banks as they exist. As the system grows, operations personnel will be able to observe when modification of the size, location, or number of capacitor banks is required.

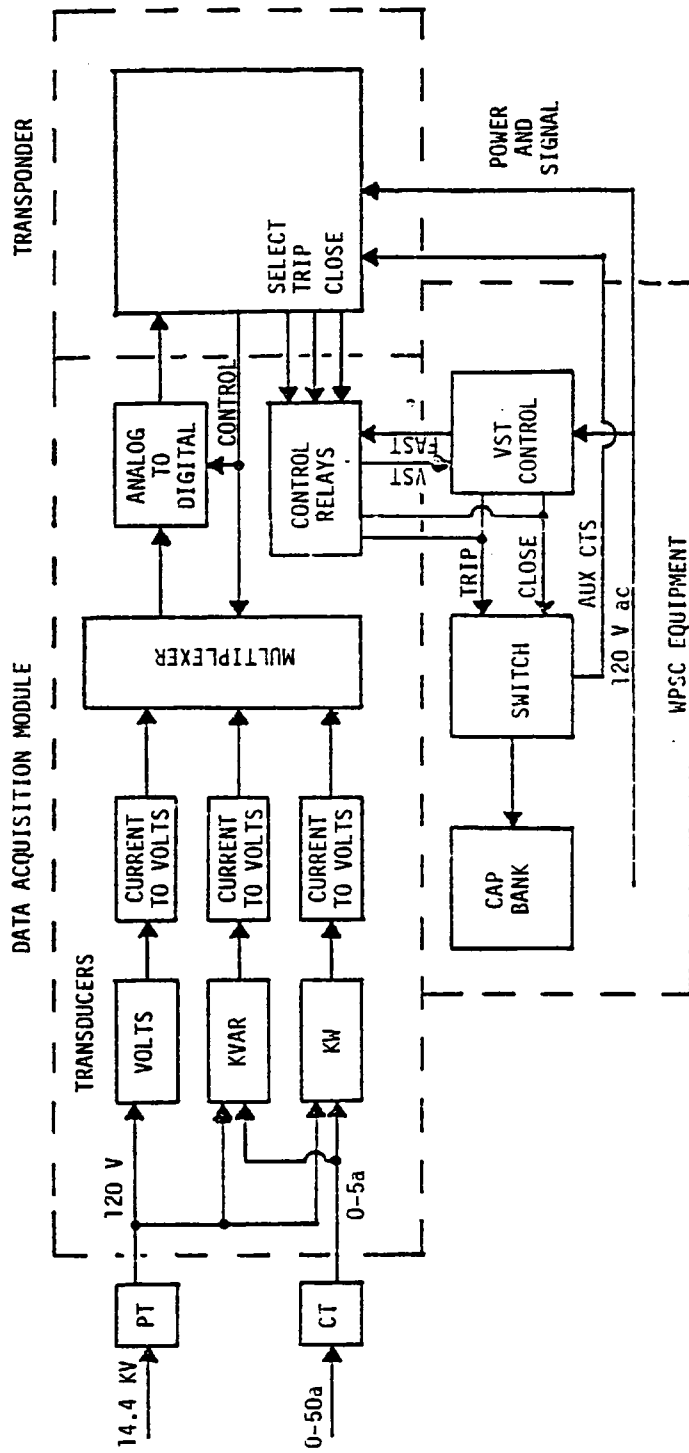


FIGURE 4 ROCKWELL DATA ACQUISITION AND CAPACITOR CONTROL TRANSPONDER

## VOLTAGE REGULATION

Long distribution lines often require voltage regulators mounted along the feeder to act in concert with substation LTC's and power factor correction capacitors to maintain customer voltage. However, rather than functioning as part of an integrated system, regulators operate independently from the other system voltage control devices. During voltage reductions, for example, remote line regulators may actually operate to defeat the best efforts of the dispatcher to control the voltage. During normal system operation, the load drop compensator may not accurately compensate for line impedance between the "load center" and the regulator.

### Regulator Accessories

Several accessory devices are available to enhance the capabilities of existing regulator controllers. The following describes some of these features and how they can also be performed by Rockwell's Feeder Automation System.

#### Voltage Reduction Kit

Allis-Chalmers, for example, offers a voltage reduction kit. The kit can be installed in most regulator controllers and provides for 2.5% and 5% voltage reductions.

#### Voltage Limit Control

Another accessory offered for the JFR/AC regulator is the voltage limit control. The limit control attempts to overcome difficulties encountered by the LDC. LDC's are set at normal feeder load levels. If feeder loading increases, voltage output increases are called for by the LDC in an attempt to keep the voltage at the "load center" at some nominal level. Overvoltage at the first customer beyond the regulator could result however. The voltage limit controller offers a partial fix for these types of problems. The controller is still limited to making judgments based on values measurable at the regulator and not at the customer terminal.

#### Reverse Power Flow Detection

If the utility desires to backfeed through a line regulator, some measures must be taken to disable the normal control function of the regulator. The LDC senses voltage on the load side of the regulator. Since the regulator is being backfed, it now senses the "source" side voltage instead of the "load" side. The reverse power flow accessory effectively moves the PT to the new load side, and reverses the influence of the LDC. However, it does not compensate for the fact that the impedance to load center in backfed situations will probably be different than when it was set to control voltage in normal operation.

The Rockwell Feeder Automation System Transponders (FAST) in conjunction with the Substation Terminal and Operator Terminal offer simple solutions to these and other difficult voltage control situations.

### FAS Transponder Voltage Regulator Control

The Rockwell Voltage Regulator FAS Transponder (VR-FAST) used to control voltage is a "smart" device. The Substation Terminal transmits the desired nominal voltage bandwidth and time delay to the VR-FAST. It then controls the feeder voltage in accordance with these parameters.

To control the phase voltage in addition to voltage monitoring at the regulator, three voltage monitoring transponders are selectively placed at critical voltage locations on the same phase of the feeder. Every 20-60 seconds (depending on scan rate selected by the Control Operator) the Substation Terminal polls the monitoring transponders. When a complete profile is assembled, the Substation Terminal analyzes the data to determine if the voltage remains within limits as specified by the operator.

The regulator secondary voltage is compared with the monitored voltages. The regulator is then set to a voltage approximately  $1/2$  the  $\Delta V$  (regulator - line end) above the established set point voltage.

$$\left\{ V_{R_{t2}} = V_{RN} + (V_{R_{t1}} - V_{LE_{t1}})/2 \right\}$$

$V_{R_{t1}}$  = Regulator Secondary at  
t1 (before adjustment)

$V_{R_{t2}}$  = Regulator Secondary after  
adjustment

$V_{RN}$  = Nominal Voltage set  
by operator instruction

$V_{LE}$  = Voltage at Monitoring  
Transponders

This action replaces the load drop compensator action with an accurate measurement of the voltage at critical locations on the phase. Therefore, the regulator controls voltage by direct measurement, instead of a voltage derived by a calculated impedance set in the compensator.

If the regulator secondary voltage exceeds 127 V in order to maintain the monitored voltage above the low limit of 116 V, then the voltage is raised to 127 V limit and on the next communication the Substation Terminal is notified. Should the voltage reach 129 V at the regulator, the VR-FAST, without communication will immediately

reduce the regulator output to 127 V and report to the Substation Terminal on the next communication. The voltage limits are checked at every location at which voltage is measured on the feeder. Any violation of these limits is reported to the Control Operator.

#### FAST Voltage Reduction

The Rockwell VR-FAST used to control the voltage regulator, controls regulator output voltage to any nominal value specified by the operator. Voltage reduction can be set to any value simply by notifying the VR-FAST of the new nominal voltage. When voltage reduction is commanded by the control operator, new upper and lower limits are calculated by the Substation Terminal, e.g. for a 5% reduction the new upper limit would be 121 V and the lower limit 110 V.

#### FAST Voltage Limit Control

The Rockwell VR-FAST constantly monitors the output voltage at the regulator. Should this voltage rise above the specified overvoltage alarm limit, the FAST notifies the Substation Terminal which in turn notifies the operator of the abnormal condition.

#### FAST Reverse Power Flow Regulation

Preliminary discussions with WPSC did not include the use of the regulator in a backfeed mode. However, as an example of the flexibility of the Rockwell Feeder Automation System, several methods of operating the FAS in the backfeed mode can be implemented.

The VR-FAST uses the raise/lower circuitry in the LDC to raise and lower the load side voltage. It is "raising" the load side voltage with respect to the source side voltage. In backfeed mode, the substation, or one of the capacitor banks equipped with voltage monitor can be employed as the monitoring transponders. The regulator simply must regulate the end of line voltage. Direct raise/lower instructions from the Substation Terminal can be used to manage voltage during this unusual situation.

### III. SYSTEM CONTROL

#### COMMAND MODES

Each transponder can function in one of 3 independent modes: Direct, Automatic or Monitor. The transponders may be placed in one of these modes by a group command from the Substation Terminal or separately by individual command. The operator must specify the mode.

##### Direct

In the direct mode, the operator may select a device and control its operation by an explicit command. The operator may instruct the selected device to trip/close (for capacitor banks) or to raise/lower (for voltage regulators). A pre and post operation feeder profile is displayed to allow verification of the command execution.

##### Automatic

In the automatic mode, the operator may change the specifications to which each of the controllers are controlling. These parameters include:

- High Volts Limit/Alarm
- Nominal Volts
- Low Volts Limit/Alarm
- Bandwidth
- Delay Time

Alarm set point violations are reported on the Substation Terminal to the operator. The VR-FAST and Substation Terminal will not allow limit violations, nor will they control so that a limit is violated.

##### Monitor

In the monitor mode, the transponders report system parameters to the Substation Terminal and the operator. This mode can be used to observe the effects of the operation of the existing voltage regulator and VST controller.

The Feeder Automation System is broken into 3 primary sub-parts. First the Central Communication Computer which handles communication between the Substation Terminal and the operator. Second, the Substation Terminal handles the communication protocol necessary to send commands to and receive data from the control transponders.

Third, the control transponders record data, receive commands, control capacitor banks or voltage regulators, and report data and status to the Substation Terminal. A discussion of each of these subsystems follows, beginning at the control transponder end of the system and ending with the Central Communication Computer.

## FEEDER AUTOMATION SYSTEM TRANSPONDERS

Phase I of the joint feeder automation development program requires 3 types of FAS Transponders to be developed. The standard Rockwell Power Line Communications Transponder is to be modified to: (1) Control capacitor banks; (2) Control voltage regulators; and (3) Record voltage readings and report them to the Substation Terminal.

Figure 1 shows the three transponder types as T1A (Type 1) a Capacitor Bank Controller; Type T2A (Type 2) as Remote Voltage Sensors; and T3 (Type 3) as a Voltage Regulator Controller.

### Capacitor Controller Transponder

Figure 4 shows the functional block diagram of the transponder and control monitor module. The block marked "relays" is further detailed in Figure 5. In Figure 5 the two modes (VST or FAST) are selected by the discrete output lines from the transponder.

If the capacitor control is placed in the Monitor Mode, relay K1 is de-energized. This allows the AC (VST controlled) relay to control the operation of the switches provided the auto/manual switch is in the auto position. If the FAST mode (either Direct or Automatic) is chosen, then relay K1 is energized, K1A opens, K1B closes and power is provided to the trip/close contacts of K2 and K3. If a close command is to be executed, K2 is energized, closing K2A and opening K2B. A close signal is provided to the capacitor bank switches.

Conversely, if an open command is received, relay K3 is energized closing K3A and opening K3B. Thus an open signal is provided to the capacitor bank switch. The B sections of relay K2 and K3 are used to prevent a simultaneous trip and close command from being issued. In the final design, these inhibit contacts may be placed in the low voltage control circuits of K2 and K3.

Note that in manual position, neither the VST controller, nor the FAST can initiate an operation of capacitor bank switches. Thus security is provided for personnel who may be required to manually operate the bank from time to time for maintenance purposes.



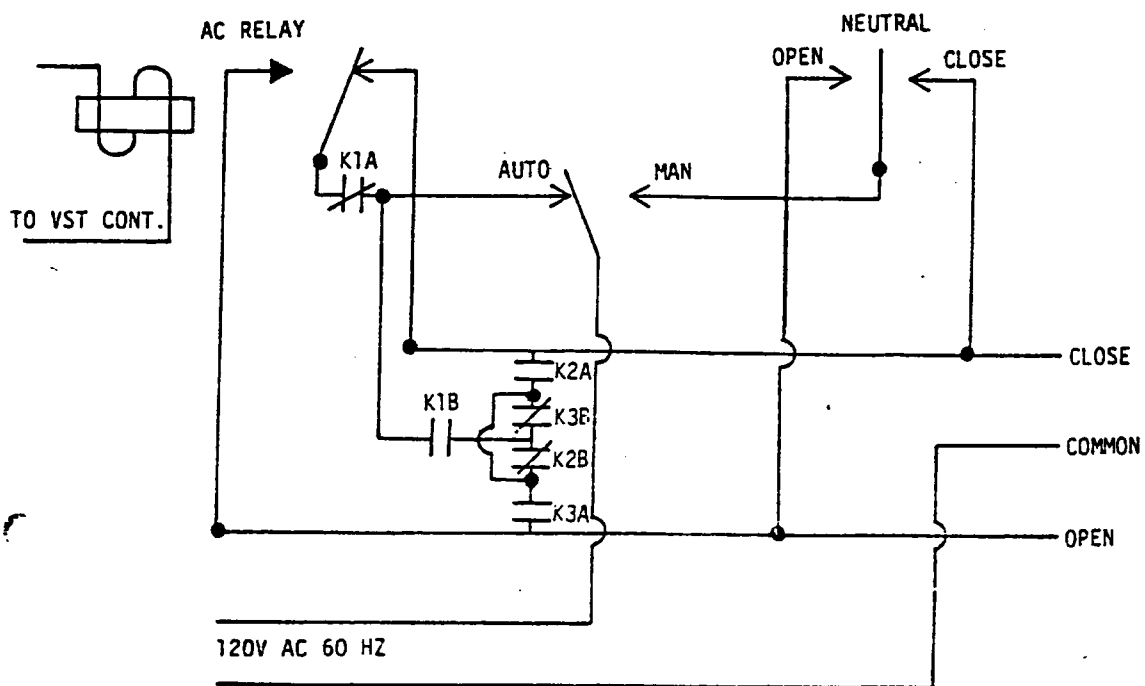


FIGURE 5 MODIFICATION OF VST CONTROLLER

## Voltage Regulator Control Transponder

The Feeder Automation System Transponder used to control the voltage regulator is very similar to the one used to control the capacitor banks. The difference is that the VR-FAST will monitor PT and CT inputs converted directly to volts instead of KW and KVARs as at the capacitor banks. Control operation will be similar to the capacitor bank. Figures 6 and 6A show the step regulator control transponder configuration. The select line from the transponder controls relay K1. Lower is accomplished by K2, while K3 raises. An inhibit scheme is used to prevent both raise and lower commands from being sent simultaneously.

Note that when the raise/off/auto/off/lower switch is not in the auto position, neither the LDC nor the VR-FAST can control the regulator.

## Voltage Sensing Transponder (T2A, T2B, T2C)

The remote voltage sensing transponders have no discrete control lines and do not require multiplexed inputs. These transponders will measure only single phase volts and report that data to the Substation Terminal when requested to do so.

## FEEDER AUTOMATION SYSTEM TERMINAL (SUBSTATION TERMINAL)

The Substation Terminal is the most intelligent unit in the Feeder Automation System. It has 3 primary duties.

1. Communicate with the Operator Terminal via phone line
2. Communicate with the transponders via power line
3. Interpret instructions and data to achieve integrated feeder voltage control.

If the operator instructs a capacitor bank to close by typing in a close command at the operator terminal, the Substation Terminal formats a direct mode instruction to the capacitor bank. The Substation Terminal gathers a feeder profile, instructs the capacitor bank to close, and then gathers an operation confirming profile. The profiles will be forwarded to the operator to confirm the operation of the system.

Similar sequences of events occur for the direct control of the voltage regulator.

In addition, the Substation Terminal will monitor the analog outputs of the SCADA KW, KVAR, and volts transducers at the substation. The Substation Terminal will encode (analog to digital) the parameters and allow their use by the Substation Terminal in controlling the feeder.

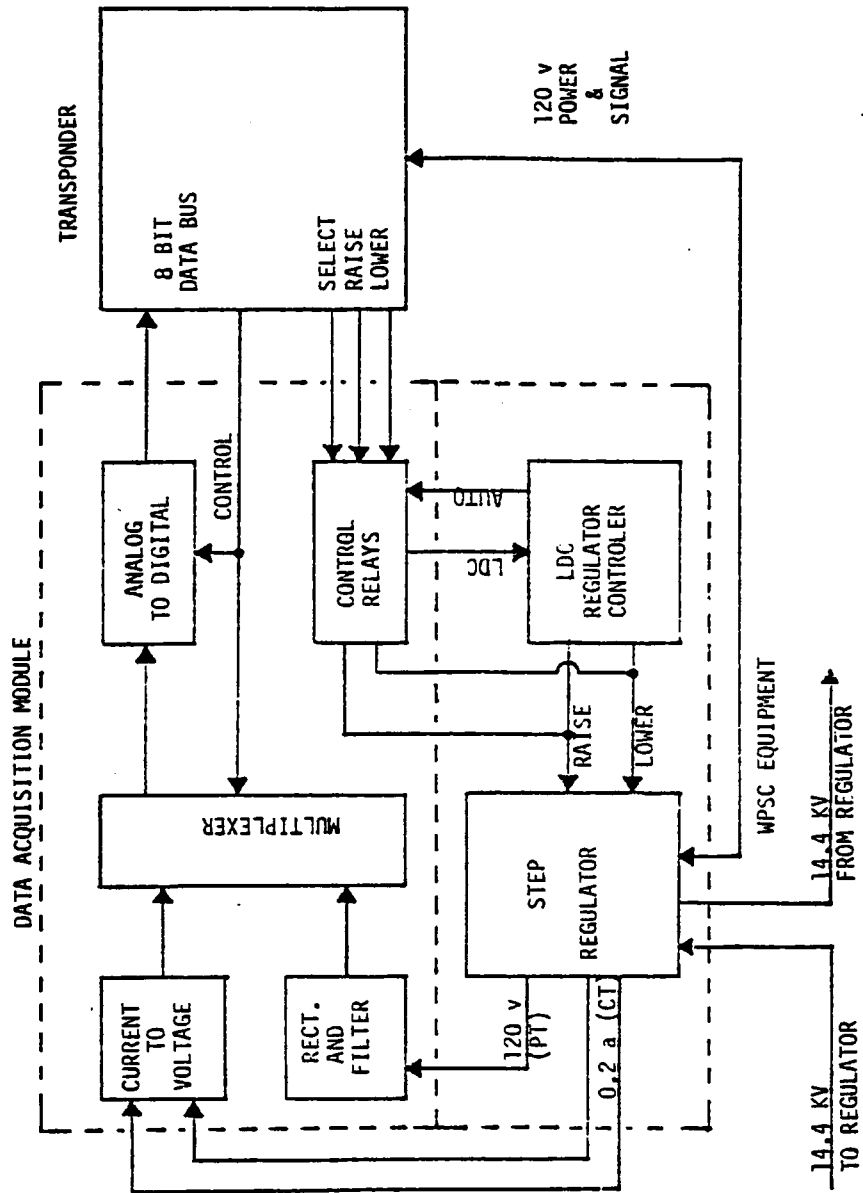


FIGURE 6 ROCKWELL STEP REGULATOR CONTROL

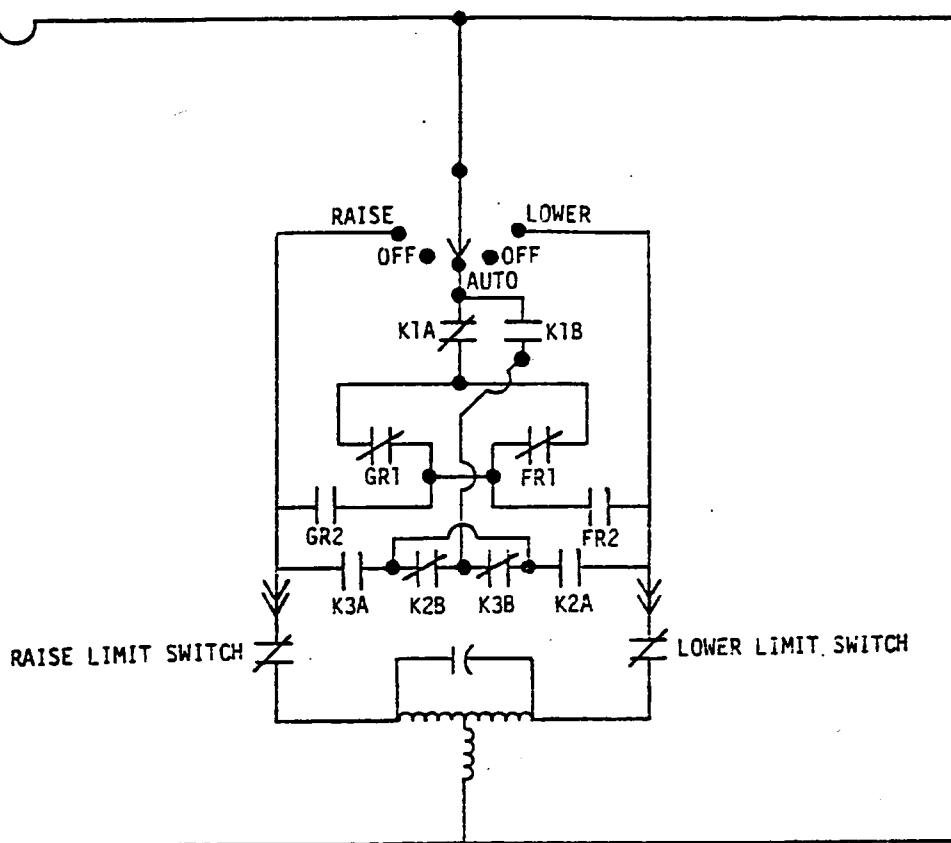


FIGURE 6A ROCKWELL CONTROL RELAY SCHEME FOR STEP REGULATOR

#### IV. HARDWARE DESCRIPTION

The hardware required to implement Phase 1 of the proposed Feeder Automation System consists of 5 primary parts. If a feeder at Antigo is chosen, power factor capacitor isolaters are already in place.

1. Operator Terminal
2. Substation Terminal
3. 6 Feeder Automation System Transponders
4. Data Acquisition and Control Modules
5. Power Factor Capacitor Isolator

##### OPERATOR TERMINAL

An Operator Terminal with phone line modem will be added. The terminal is a standard RS232, modem interfaced, full-duplex terminal.

##### SUBSTATION TERMINAL

The Substation Terminal is a slightly modified version of the Substation Controller employed in the WPSC Power Line Communications System. The Feeder Automation System Terminal designation alludes to the expanded intelligence resident in the ST to perform the feeder automation control, operating, and reporting functions. WPSC is already familiar with the communication technique, so no further description will be made of it here.

##### FEEDER AUTOMATION SYSTEM TRANSPONDER

The Feeder Automation System Transponder is also a microprocessor based unit. It was designed to allow great application flexibility while remaining a relatively simple/reliable device. Two microprocessors provide sufficient intelligence for any Feeder Automation System application. One is dedicated to the communications tasks, while the other performs control and data acquisition functions.

##### DATA ACQUISITION AND CONTROL MODULE

The Data Acquisition and Control Modules for the capacitor controllers contain voltage, KW and KVAR transducers. The regulator control transponder contains voltage and current transducers. The remote voltage monitors contain only voltage transducers. The regulator and capacitor control modules also contain relays to control the open/close switches for capacitor banks and raise/lower for the regulator.

##### POWER FACTOR CAPACITOR ISOLATOR

Capacitor Isolators are installed at Antigo and no additional units will be required.

## V. BENEFITS TO WPSC

A benefit to WPSC in development of automated distribution is that WPSC will share in the ultimate form and control philosophy of the automated distribution system. The distribution operating experience gained over the years by WPSC personnel can be transferred to the Distribution Automation System being developed by Rockwell.

Another benefit that accrues to WPSC is experience. WPSC will be among the first utilities in the nation to have actual experience with Feeder Automation. WPSC will be able to evaluate firsthand the potential of a bidirectional communication system for control of the distribution system. This voltage control project will aid WPSC in being able to evaluate more of the generic strengths and weaknesses of any such system. WPSC will be in an excellent position to evaluate future, more extensive distribution automation systems as a result of this project.

Just as in the load survey capabilities of WPSC/Rockwell Power Line Communications System, the ease of data gathering will provide additional capacity for studying and understanding distribution systems. This will provide WPSC with the necessary operating strategies for reducing operating cost. One example which will first become apparent with the Distribution Automation System is capacitor bank sizing. Immediate feedback concerning VARS at each bank and the effect on overall substation power factor will become apparent. The usefulness of this knowledge in optimizing the installation cost and operating effectiveness of the distribution system is a significant advantage to WPSC and justification to proceed with this project.

## VI. W.P.S.C. SUPPORT

There are three periods which are critical in the successful completion of this project which will require timely, dedicated WPSC effort.

1. Design: The control philosophies which WPSC wishes to use have a great impact on how the software for Transponders, Substation Terminals, and Operator Terminal will be written. Complete accord must be reached on capacitor control and voltage regulator control philosophies upon commencing this development project.
2. Installation: While Rockwell provides all the assistance necessary for orderly installation of the Feeder Automation System, WPSC should take every opportunity during this period to become familiar with the Feeder Automation System. Capacitor bank isolators, PTs, CTs or other items which require work on primary voltages will be installed by WPSC personnel. It is anticipated that WPSC will install all hardware and select the locations for the monitoring transponders.
3. Operation: Continuous feedback on the operation of the Feeder Automation System from WPSC to Rockwell insures the Phase II expansion of the FAS occurs as smoothly as possible. It will also insure that updates to the Phase I system are incorporated with maximum efficiency and minimum disturbance to the WPSC system.

## VII. SCHEDULE

Rockwell is prepared to move forward with the orderly implementation of Phase 1 Feeder Automation System development immediately. The schedule in Figure 7 shows how the implementation of the Feeder Automation System will be accomplished, assuming a go-ahead date of July 1, 1980.

Rockwell expects that during software design, WPSC personnel will be heavily involved in the design of the software philosophy. Based on agreed upon control philosophies, Rockwell will finalize a system design, procure parts, and fabrication of the units involved will begin. Software changes in the ST to provide feeder profile reports and command selection to the operator will also begin in Item 1.

In November, the hardware for the FAS Transponder/Controllers will be completed and tested. The software will be integrated with each respective controller, the Substation Controller, and the Central Operator Terminal. When the system performs satisfactorily on Rockwell's test bed, and the hardware and software have been completely exercised, it will be brought to Antigo Substation. A 2 1/2 month period of installation and field testing will follow, during which time WPSC personnel will gain experience operating the system.



# PROPOSED SCHEDULE

WISCONSIN PUBLIC SERVICE CORPORATION  
AND  
ROCKWELL INTERNATIONAL

## ANTIGO SUBSTATION DISTRIBUTION AUTOMATION PROJECT

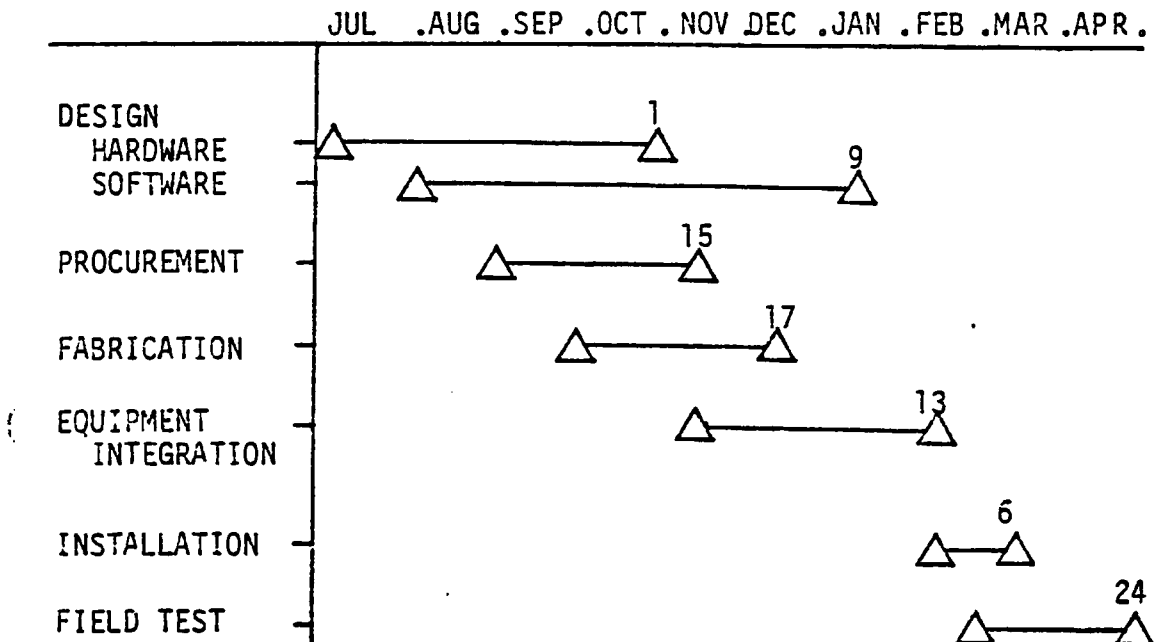


FIGURE 7

## APPENDIX C

ENVIRONMENTAL CHAMBER TEST OF CAPACITOR  
ISOLATOR REACTOR MANUFACTURED BY TDC

## NOTE TO APPENDIX C AND D

At the request of my committee, I have included reports titled "Environmental Chamber Test of Capacitor Isolator Reactor Manufactured by TDC" and "Environmental Chamber Test of Most Recent Production Run of Capacitor Isolator Reactors Manufactured by TDC" as Appendix C and D of this report. I am not able to include the high quality photographs which the report originally used, since they are no longer available. The committee and I agree that the actual content of the photos is not essential to the evaluation of technical value of the reports.

TJT  
10-1-80

ENVIRONMENTAL CHAMBER TEST  
OF  
CAPACITOR ISOLATOR REACTOR  
MANUFACTURED BY TDC

ENVIRONMENTAL CHAMBER TEST OF CAPACITOR  
ISOLATOR REACTOR MANUFACTURED BY TDC

INTRODUCTION

Field experience with TDC Isolators indicated that a potential thermal expansion coefficient problem exists between the epoxy body of the inductor and the porcelain insulator which supports it. Several claims and counter claims have been made concerning the failure mode of the epoxy isolator. It was decided to place a small sample of the isolators in the environmental chamber at Rockwell's Dallas facility to determine the susceptibility of these units to cracking.

Three units were placed in the environmental test chamber. Five amps RMS continuous current was run through the inductors throughout the test period to simulate continuous operation of an associated capacitor bank. The reactors were lowered from 20°C to -40°C and observed carefully overnight. Cracking developed in two out of three of the units which were from early production runs. The most recent production run of TDC isolators did not exhibit any cracking.

Photos were taken in the cold chamber to document the places at which the reactors failed. After nearly 24 hours at -40°, the reactors were raised to 0° and then returned to -40° so that any further cracking due to cold weather temperature cycling could be noted. The reactors were then raised to +50°C and left for a few days. No additional significant cracking was noted other than expansion of existing cracks induced during the first cold cycle. Again the unit from the most recent production run of TDC isolators did not exhibit any surface cracking failures under these tests. However, recent field experience at Snapping Shoals indicates that further testing of this production run should be performed prior to lot acceptance.

From these tests it can be concluded that at least two of the production

## INTRODUCTION (continued)

runs of the reactor isolators supplied by TDC contained units which were not capable of surviving the temperatures specified in Specification #090-0109-668 to which the reactors were supposed to be designed. The units were tested while vertically mounted to relieve TDC's concern over mechanical stresses. The units were tested with continuous five amp current running through them to simulate the continuous operation of an associated capacitor bank. Under all these carefully controlled conditions, two out of three of the units provided by TDC developed cracks in the epoxy body.

## TEST SET UP

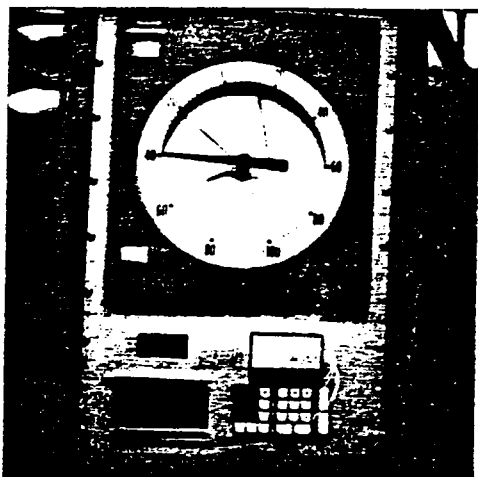
Several environmental test chambers are available at the environmental test facility at Rockwell-Collins Dallas facility. A large chamber was selected for its computer controlled temperature humidity facilities and data logging capabilities. In addition, it was felt that a larger chamber would prevent any thermal shock to the isolators from occurring due to visual inspections which required the chamber doors to be opened and photos to be taken. The outside of the environmental chamber used is shown in Photo 1. The door shown in Photo 1 opens into the control and monitoring room of the environmental chamber. The environmental chamber's refrigeration and heating equipment is controlled by microprocessor controller shown in Photo 2. The large dial at the top indicates the temperature within the chamber in degrees centigrade. That same temperature is inscribed on a chart (see appendices) beneath the indicator so that a time log of the chamber's actual temperature can be maintained. Thermocouples may be placed on devices in the chamber to measure their temperature.

A portable data logger which continuously logs the time and temperature of each of the thermocouple channels was used. This thermocouple, data logger is shown in Photo 3.

Photo 4 shows the arrangement which was used to provide five amps RMS current to the reactors. A variac was connected to a filament transformer,



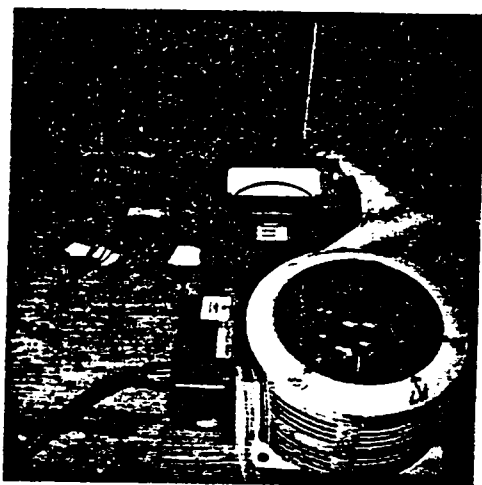
1. ENVIRONMENTAL CHAMBER



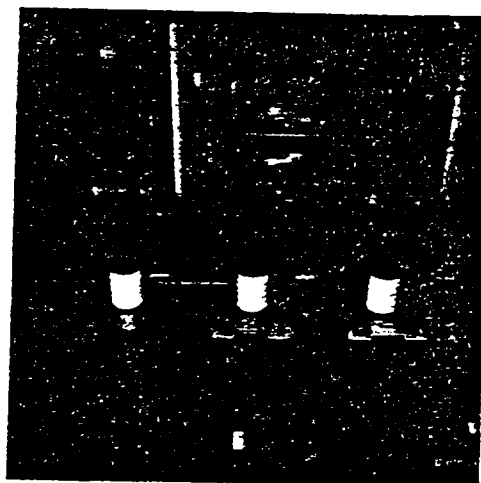
2. THERMAL PROGRAMMER & RECORDER (-40°C)



3. THERMOCOUPLE DATA LOGGER



4. AMMETER, VARIAC, TRANSFORMER  
TO GENERATE 5 AMPS



5. REACTORS IN CHAMBER  
MOST RECENT, 2ND RUN, OLDEST  
FROM LEFT TO RIGHT



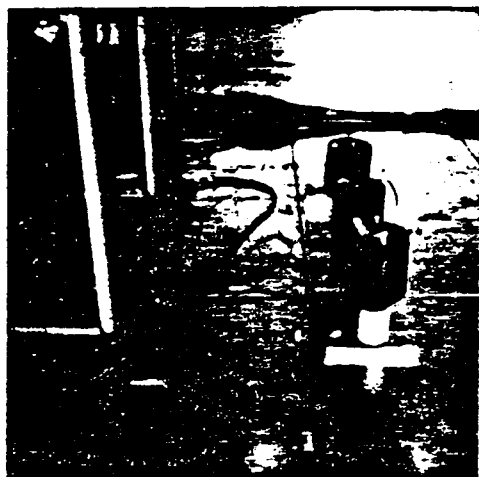
#### TEST SET UP (continued)

the secondary of which was connected in series with the three reactors. An RMS ammeter was also placed in the secondary of the filament transformer, thus indicating (on high range) nearly five amps current flowing continuously during the test. The variac, transformer and ammeter are shown in Photo 4. All the above mentioned pieces of equipment were in the control and monitoring room of the environmental chamber.

Within the environmental chamber, the three reactors under test were placed on the floor mounted vertically on stands. Photo 5 shows the reactors as they were arranged on the floor of the test chamber before testing began. These reactors will be referred to as the new reactor which is shown on the left, the old reactor which is shown on the right, and the middle reactor which is in the center. Note that the new reactor is coded on top by TDC with white stenciled letters. The middle reactor is mounted on a plate which has a red Rockwell insignia on it and the old reactor does not have a rounded base joint as will be more evident in photographs which follow. Arrangement of these reactors on the floor is shown in Photo 5. The reactor which is called the new reactor, and is in the left of Photo 5 is also at the north end of the chamber. Photo 6 was taken standing at the north end of the chamber looking south at the three reactors, the nearest being the new reactor, the farthest being the old reactor. Photo 6 shows the attachment of thermocouples and the series five amp secondary of the filament transformer. Photo 7 shows the same state of test preparation prior to beginning the environmental test.

#### TEST PROCEDURE

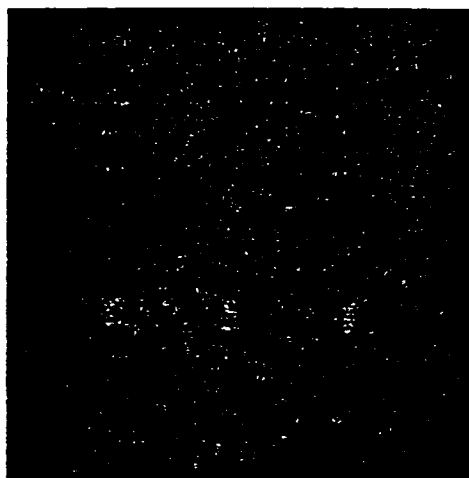
At approximately 1:00 p.m. on 27 August 1980, the reactors were installed in the environmental test chamber as previously shown in Photo 7. At 1:30 programming of the temperature in the environmental test chamber began. At approximately 1:40 p.m. the computer was instructed to take the environmental test chamber from its present temperature down to  $-40^{\circ}$  in a period of approximately one and one-half hours. A little after 3:00 p.m. the same day, Tom Talley and Tim Herron entered the chamber and observed the reactors.



6. THERMOCOUPLES ATTACHED



7. 5a SERIES CIRCUIT INSTALLED



8. -40°C

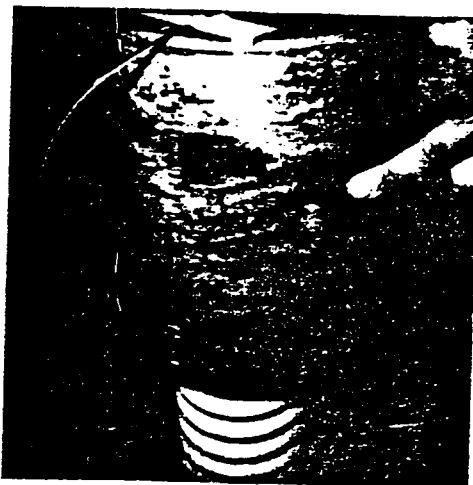
## TEST PROCEDURE (continued)

The reactors were closely inspected for cracking. At that time no cracking was noted.

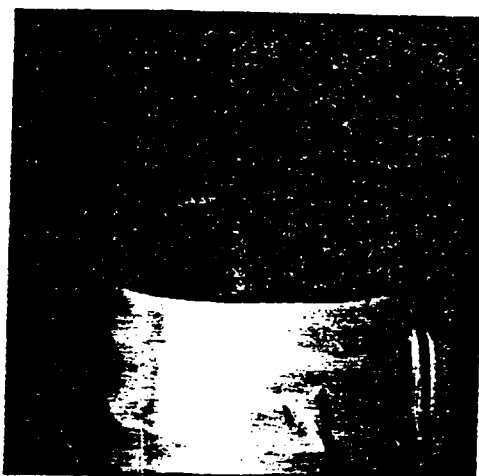
The reactors were left in the chamber undisturbed overnight with five amps current flowing through them and the temperature at  $-40^{\circ}\text{C}$ . They were inspected the following morning at approximately 10:45. Cracks were noted. Photo 9 shows the beginnings of a crack in the body of what is called the oldest or south reactor. Cracks were of the type which might be characterized as being caused by a hatchet chop in the epoxy. They were two or three inches in length and appeared to be of substantial depth. In addition to the cracking in the main body of the reactor, hairline cracks were beginning to form in the neck of the reactor where the porcelain insulator joins the epoxy main body. After these observations were made, the reactors were left undisturbed until nearly 24 hours "cold soak" had elapsed at which time photographs were taken to document the failures occurring in the isolators.

At approximately 1:00 p.m. photos were taken to document cracking of the old and middle isolator reactors. Photos 9 and 10 show the body and neck cracks developing in the old isolator inductors. The quality of the photos is sufficient only to indicate the general vicinity in which the crack occurs. It is not intended that the photo document the extent of cracking, only to identify which crack occurred at the cold temperature. Actually, no cracks formed other than those which formed during this first cold period, rendering photos of progressive events unnecessary. As shown in Photo 10, a hairline crack of the neck of the old reactor is beginning just under the seam which appears as a horizontal white bridge. The middle inductor also sustained body and neck cracking. Photo 11 shows a crack in the neck of the middle inductor as well as an area which had been sanded after production. Photos 12, 13 and 14 indicate the position of a crack which formed between the terminals on top of the middle inductor, and extended across the top of the inductor parallel to thermocouple wire and down the side of the inductor.

OLDEST REACTOR



9. CRACK IN BODY



10. CRACK IN NECK

## TEST PROCEDURE (continued)

After the documentation photographs were taken, the inductors were raised to 0° to simulate transition from darkness to daylight in the Green Bay area.

Photo 15 shows the isolators in the chamber after being raised to 0°. Since the isolators were the coldest thing in the chamber during the period of time when the chamber was transitioning from -40° to 0°, frost formed on them. This is a phenomenon which might be expected to occur in nature. The chamber was raised to a temperature slightly above 0° so that the frost would melt and direct observation of the epoxy could be made. The temperature was raised at approximately 4:00 p.m. 28 August, 1980. At approximately 10:00 p.m. the inductors were observed. No additional cracking in the body of the inductors or in the necks were observed due to the upward transition and stabilization at 0°. The chamber was taken back down to -40°C over a one hour period from approximately 10:30 p.m. 28 August 1980 to 11:30 p.m. on the same date. The inductors were left at -40° until the following morning at 9:00 a.m. when they were observed again.

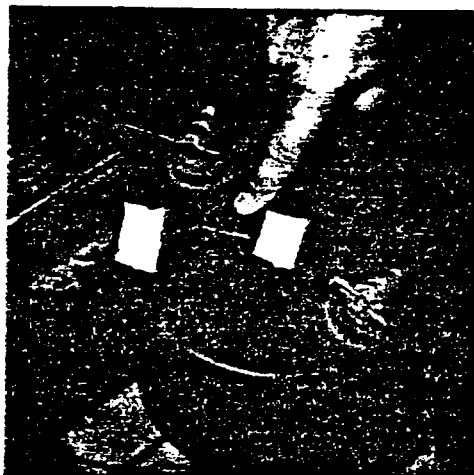
No cracking in either the old, middle or new inductors was noted other than the expansion of already existing cracks.

It was decided at that point to determine whether or not high temperatures as well as low might cause cracking in the inductors. Therefore, the chamber was programmed to go from -40°C to +50°C in 144 minutes. This change rate provided the same ramp rate as that used previously. The chamber reached +50°C at 1:00 p.m. 29 August 1980. After the reactors had an opportunity to stabilize thermally, they were again observed. At 4:00 p.m. no new cracks had been observed. After 24 hours at +50°C the chamber heater was turned off and the chamber allowed to coast down to room temperature. The inductors were observed again and no new cracking was observed.

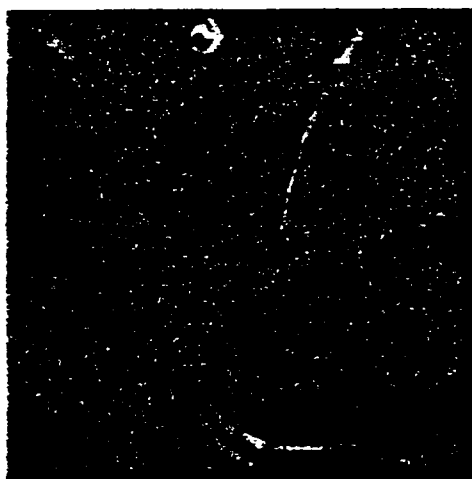
## 2ND PRODUCTION RUN -40°C



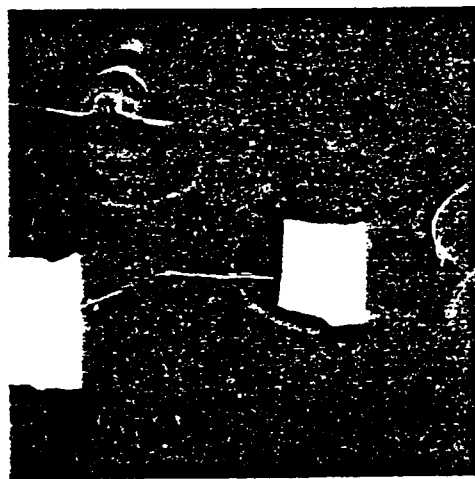
11. -40°C CRACK IN NECK



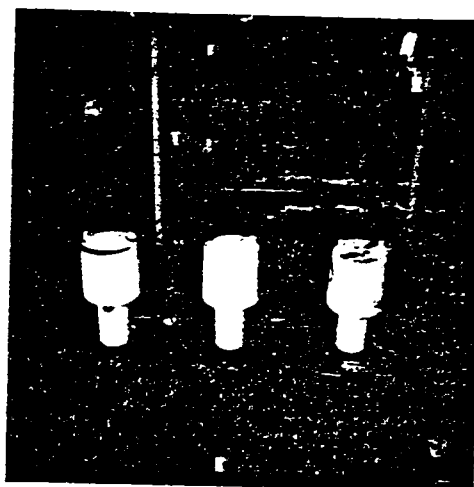
12. CRACK ACROSS TOP



13. CONTINUES DOWN SIDE FROM PHOTO 12



14. SAME AS 12 - HARD TO SEE



15. FROST FORMED 0°C

### CONCLUSION

An inductor from the oldest production run of TDC capacitor bank isolator inductors cracked when placed in an environmental chamber and exposed to a temperature of  $-40^{\circ}\text{C}$ . The inductor from the middle production run of isolators, cracked when placed in an environmental chamber and exposed to a temperature of  $-40^{\circ}\text{C}$ . The newest production run of TDC isolators did not develop any surface cracks when placed in an environmental chamber and exposed to a temperature of  $-40^{\circ}\text{C}$ .

Continuous current was run through all three inductors in series. The values of current was approximately five amps to simulate that which might occur due to unbalance when the reactors were used in the neutral of a capacitor bank. Under these temperature transitions and continuous current conditions, two of three TDC isolators cracked both in the epoxy body and in the neck.

Copies of photos taken after the conclusion of the environmental test and copies of the chamber time-temperature charts are attached. The data recorded by the thermocouples is on a long strip of printer paper, a copy of which can be provided upon request.



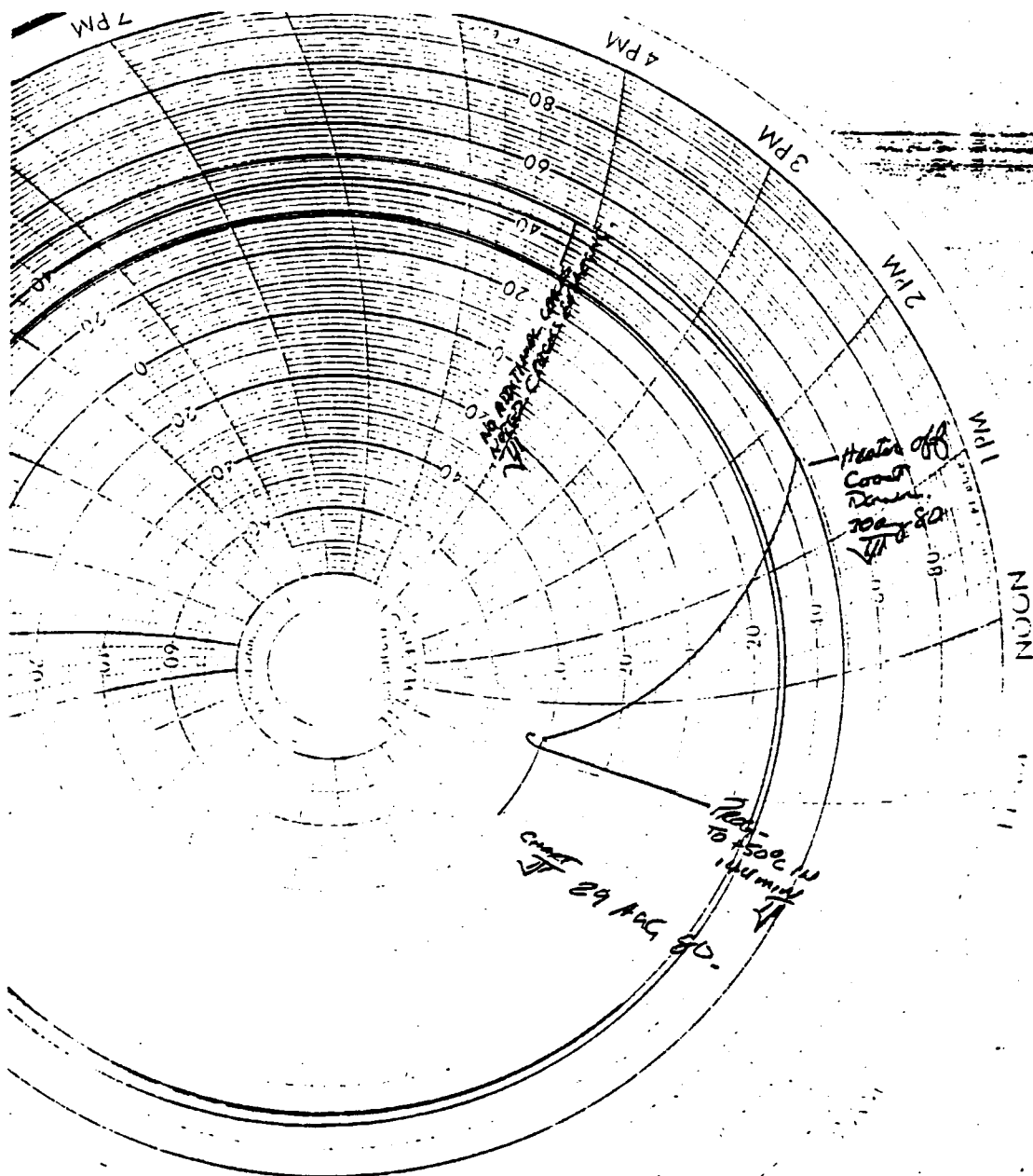
**APPENDIX**

**Temperature Charts**

**Photos of Units after Test**

**Tim Herron's Report on Field Failures and Location of Isolators**

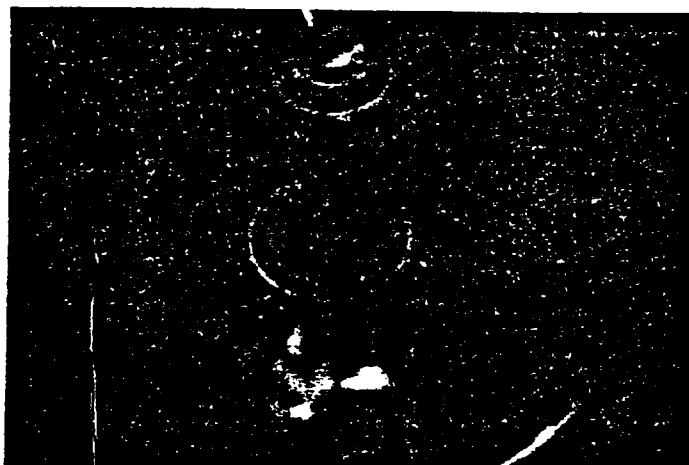




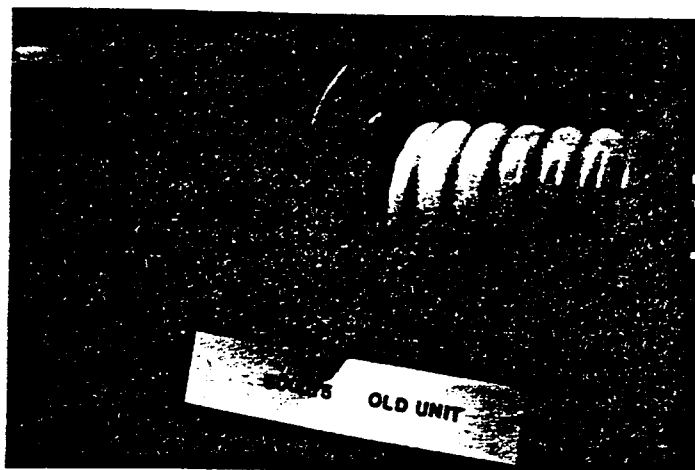
MIDDLE UNIT



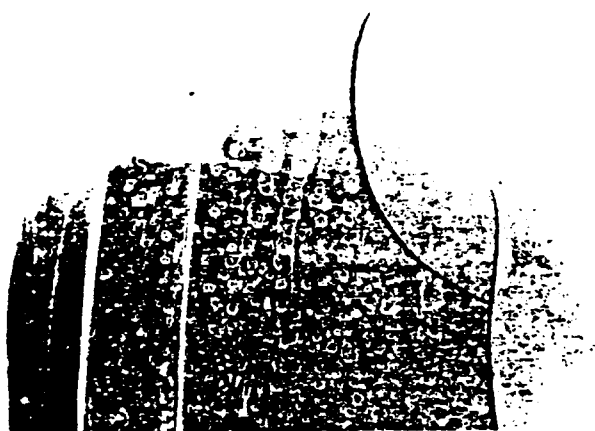
TOP OF MIDDLE UNIT



OLD UNIT



SIDE OF OLD UNIT



29 September-80

R. A. Arrington

Tim Herron

## Cracked Isolator Documentation

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This letter documents all presently known TDC Isolator failures where epoxy cracking has occurred. Listed below is the location where the failures were reported and serial number of each unit. Photographs of each unit have been taken. Additional documentation of isolator failures is presented in a report by Tom Talley concerning isolator environmental test.

<u>COMPANY</u>	<u>UNIT SERIAL NUMBER</u>	<u>DATE RECEIVED</u>
WPSC	500117 500121 500105	5-6-80
Utah	500088	8-26-80
Snapping Shoals	500325 500301 500308 500296 500309 500324	9-24-80  Note: Units never installed
Rockwell Inter- national UCS Isolator Environmental Test	500075 500040	
Thermal Equilibrium Test	500130	



T. W. Herron

TWH:dt

cc: T. Talley

**APPENDIX D**

**ENVIRONMENTAL CHAMBER TEST OF MOST RECENT PRODUCTION RUN OF  
CAPACITOR ISOLATOR REACTORS MANUFACTURED BY TDC**

RECEIVED

JAN 13 1982

Technical Support

12 JAN 81  
TJTENVIRONMENTAL CHAMBER TEST OF MOST RECENT PRODUCTION RUN OF  
CAPACITOR ISOLATOR REACTORS MANUFACTURED BY TDCINTRODUCTION

As previously indicated in the report titled "Environmental Chamber Test Capacitor Isolator Reactor Manufactured By TDC", field experience with TDC Isolators indicated that a potential thermal expansion co-efficient problem exists between the epoxy body of the inductor and the porcelain insulator which supports it. A sample of one isolator from each production run was placed in an environmental test chamber at the Rockwell Dallas facility. Although the limits of such a small sample in understanding real product reliability are understood by Rockwell UCS, failures of the older production runs and the lack of failure of the newest production run indicated that there was perhaps a chance that the newest production run would survive the temperatures originally specified for the product (-40°C to +50°C). Therefore, a sampling procedure was established for sampling of the last production run of TDC isolators which were available.

An effort was made to determine a generally acceptable sampling method. Mil Standard 105D (MIL-STD-105D) was selected as an acceptable sampling procedure. Due to the previous field failures and small batch sample failures, it was determined that tightened inspection technique should be used. Table 1 of Mil Standard 105D indicates that for unit production lots from 151 to 280 that fall under general inspection level II, Code Letter G applies. Page 18, Table IV-B, titled "Multiple Sampling Plans For Tightened Inspection Master Table" indicates the sample size acceptance and rejection criteria for various acceptable quantity levels. That table is summarized in a memorandum dated 06 October 80 titled "Tightened Inspection Test Plan". Acceptable quality level (AQL) indicates a level of failures which for purposes of sampling inspection can be considered satisfactory as a process average. Both 1% and 4% acceptable quality levels were evaluated. Even under the 4% acceptable quality level/multiple test plan at least 16 isolators had



12 JAN 81  
TJT

to be tested with no failures. However, 8 isolators could be tested, and the lot rejected if 2 of the 8 tested failed. Therefore, it was decided to minimize the risk of damaging a great number of isolators by pursuing a multiple test plan based on tightened inspection test criteria and a 4% acceptable quality level. This does not imply that 4 units failing of 100 units from TDC would be a truly acceptable quality, it merely indicates a test plan trade off for statistical purposes and provides a measure of the significance of the problem.

#### TEST SAMPLES

A sample of 20 TDC isolators was selected at random by field personnel for the environmental test described herein. These 20 were removed from service at a UCS customer site and shipped to the UCS office in Dallas. Upon arrival the units were inspected, and 6 were found cracked at the neck. One had a scuff mark which was considered not disqualifying for the test. Therefore, there were 14 isolators which arrived at UCS Dallas office which were good units available for testing. Of the 14 units it was decided to test first multiple sample size of 8 and determine whether or not the batch could be rejected. Under the multiple test plan as selected, the production run of TDC isolators could be rejected if 2 of the sample lot of 8 failed the environmental chamber test.

#### TEST PROCEDURE

For this test the capacitor isolator inductors will be referred to by two different numbers for each inductor. First number termed "Tag Number" refers to a tag which was stuck on the isolator when it left the UCS customer site. On the tag was written the inspection results prior to shipping. That tag number is cross referenced to the serial number of the inductor which was stamped on by TDC at production, and that cross reference is supplied as an appendix to this report.

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The environmental chamber used for testing would not hold 8 of the inductors simultaneously. Therefore, 4 TDC isolators were placed in the chamber at one time.

Thermal shock in air test recommended by ANSI Standard RS-186-E-78 Part 11 entitled "Standard Test Methods For Passive Electronic Component Parts Method 11: Thermal Shock In Air", was selected as a general guide to follow in testing.

Due to the fact that only one environmental test chamber was available, transition times between temperatures were somewhat longer than described in the Standard. The minimum temperature transition period available was approximately 1.5 hours. As recommended by Table 2 of the ANSI Standard, the minimum time for temperature stabilization of the specimen of approximately 80 pounds is 240 minutes or 4 hours. That minimum time period was chosen to minimize the test time. Test Condition A was implemented except that the coldest temperature was  $-40^{\circ}$  and the highest temperature was  $+50^{\circ}$  based on the original specification letter from Rockwell to TDC. Charts 1 and 2 are records of the temperatures in the chambers during the tests.

The first batch of isolators consisting of Tag Numbers 5, 3, 19, and 2 were loaded into the environmental chamber at approximately 2:30 p.m. 11/10/80. The chamber was programmed for the temperature profile  $+50^{\circ}$  for 4 hours and immediate transition to  $-40^{\circ}$  for 4 hours with a transition period of approximately 1 hour. At 9:00 a.m. the following morning (11/11/80) as noted on Chart 1, the chart was checked and the temperature determined to be cycling properly. At 11:45 a.m. (11/11/80) the inductors were observed by Mr. Jack Smart, Director of Engineering; Mr. Tom Talley, Research Specialist; and Mr. Bob Barr, R&D Laboratory Technician. At that time it was noted that Isolator Tag Number 2 which had the scuff mark between the main body and the base was exhibiting no further expansion of that scuff mark or cracking. Tag Number 19 was exhibiting a crack between the porcelain and epoxy at the

25 NOV 80  
TJT

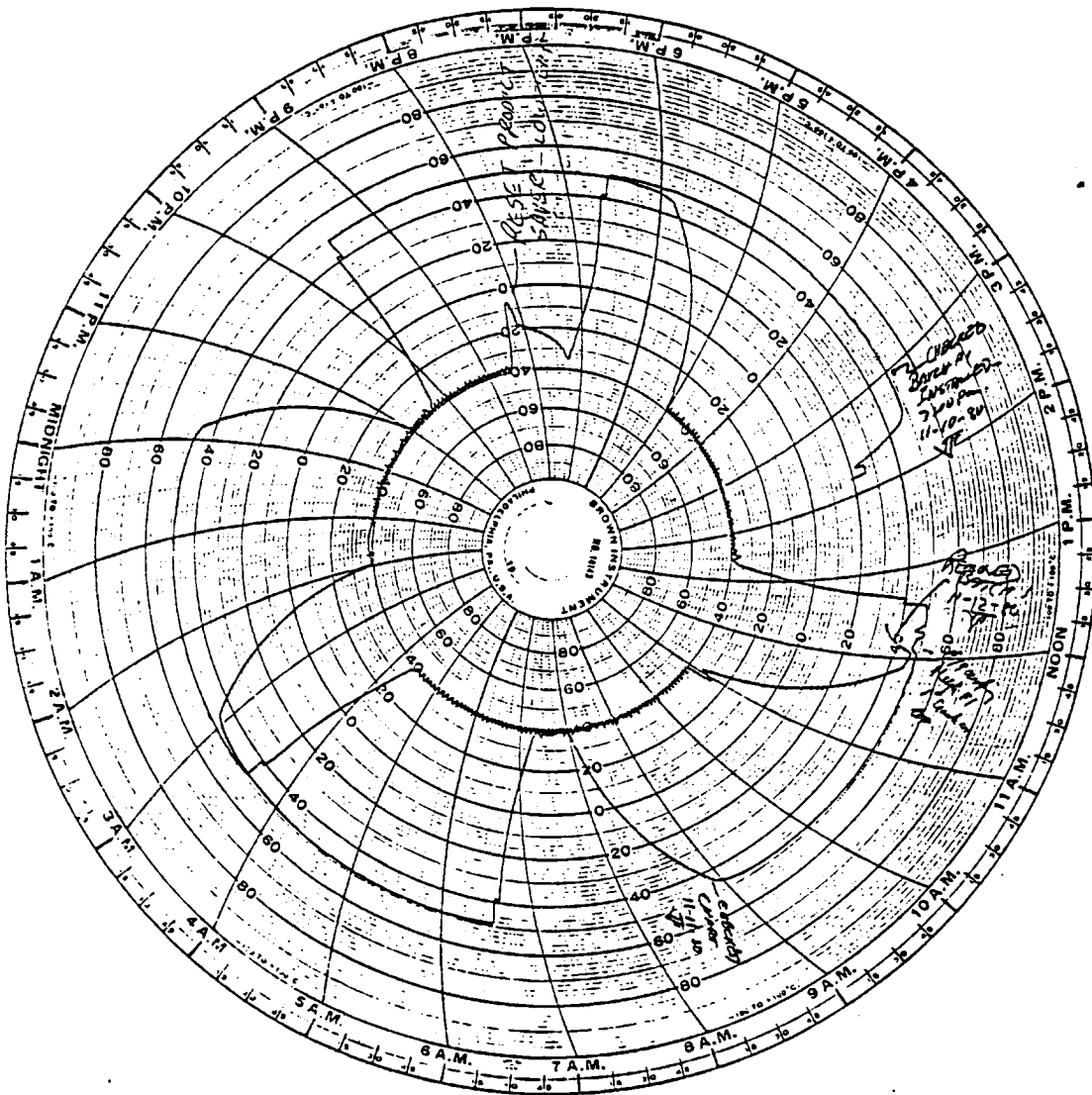


CHART 1.

25 NOV 80  
TJT

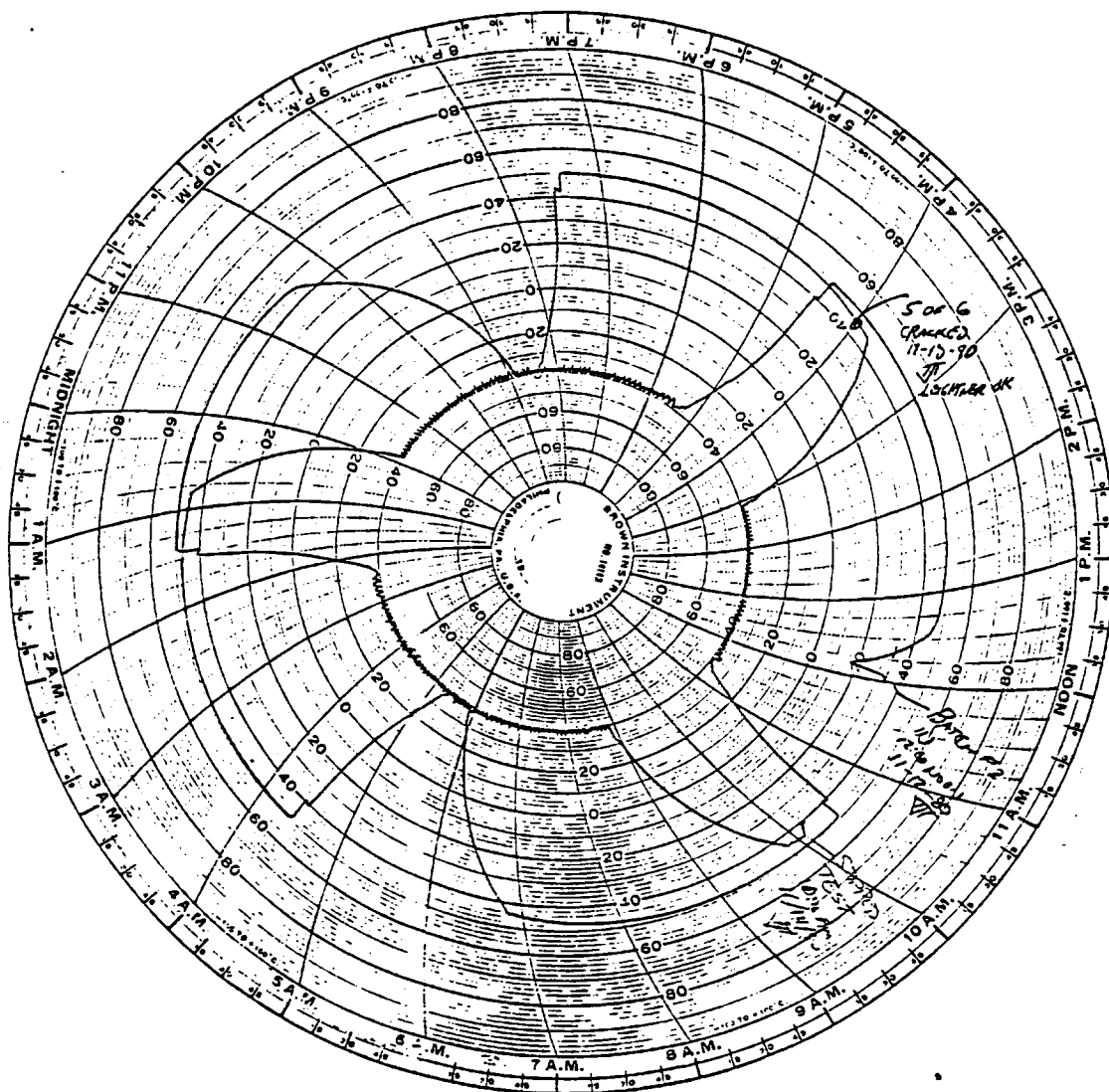


CHART 2.

12 JAN 81  
TJT

base of the neck. The crack is one which appears to be in the sealant which was applied to the neck of the porcelain and propagated from the sealant up into the epoxy.

After five temperature cycles, the devices were removed from the chamber at approximately noon on 11/12/80. As the inductors were removed from the chamber the following status was noted:

Tag Number 5: No cracks were noted.

Tag Number 3: Was exhibiting the same kind of cracking that Tag Number 19 did, the cracks extend between the epoxy and the porcelain at the base of the epoxy neck which extended up into the epoxy both longitudinally and laterally. The cracks extend approximately three-quarters of the circumference around the epoxy base.

Tag Number 2: No additional cracking noted.

Therefore, out of the first batch of 4 tested, 2 epoxy isolators cracked around the neck.

Tag Numbers 4, 6, 10, 16, 17 and 18 were loaded into the chamber for the second run. Tests of this second group of isolators began at approximately 11:55 a.m. on 11/12/80. The temperature cycling of this group is shown on Chart 2.

At 10:00 a.m. on 11/14/80 isolators for the second test run were removed from the environmental test chamber after five cycles of the test.

Tag Number 4: Neck cracking.

Tag Number 10: Neck cracking.

Tag Number 17: Neck cracking.

Tag Number 18: Neck cracking.

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In addition, other TDC isolators which are not in the random selection process but which were in the chamber, Tag Number 6 and Tag Number 16 both exhibited neck cracking.

After the inductors were removed from the chamber they were brought back to the UCS office where photographs were taken. Photo No. 1 is of Inductor Tag Number 2 indicating the scuff mark above the tag. The scuff mark did not seem to exhibit a tendency to increase in size during the environmental test.

Photo No. 2 shows Tag Number 3. Across the right side of Tag Number 3 at the neck of the epoxy, a crack between the epoxy and the porcelain can be seen at the base of the epoxy and right above the tag. This crack extends from that point to the insulator and then around the interface between the epoxy and the porcelain. Tag Number 19 is shown in both Photo No. 3 and 4. This cracking was some of the most severe noted during the environmental test extending approximately three quarters of the way around the neck.

Photo No. 5 indicates the performance of Inductor Tag Number 10. Cracking similar to that noted in other inductors can be seen. Photo No. 7, Tag Number 17, Photo No. 8, Tag Number 18, also shows the same kind of neck cracking. Photograph No. 6 shows Inductor Tag Number 4 and shows some of the first porcelain cracking observed in these tests.

### RESULTS

Of the first 8 TDC isolators tested, 6 failed. Each of the 6 failed in the neck. The test conducted was considerably less severe than ANSI Standard-RS-186-E-78 Part 11 in that the transition periods were held to approximately one and one-half hours rather than 15 minutes. In addition, temperatures were within the limits required by the original specification to TDC under which these items were manufactured. The cracking noted in these environmental tests was very similar to the cracking noted in failed units which have been returned from the field.

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TJT

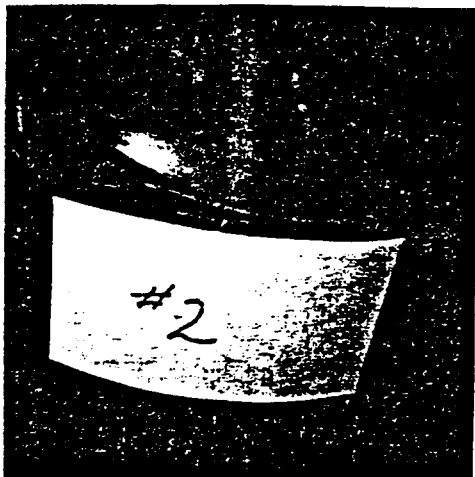


PHOTO NUMBER 1

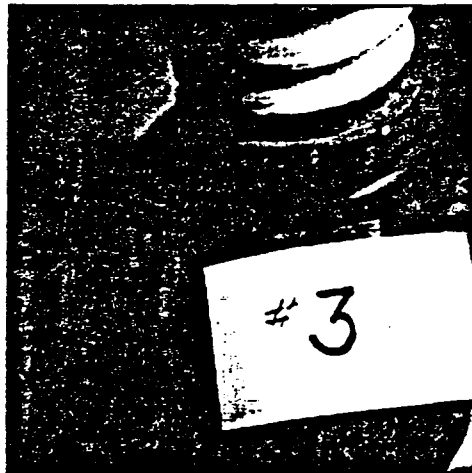


PHOTO NUMBER 2

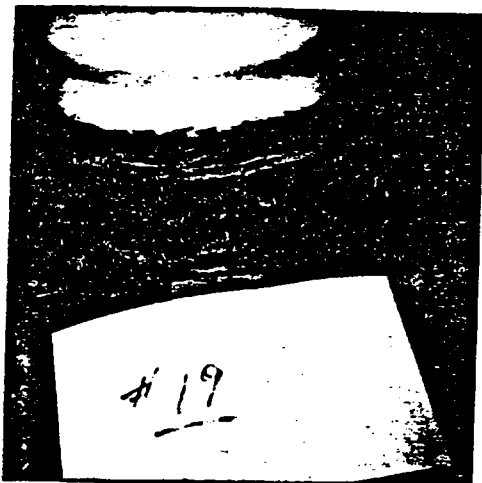


PHOTO NUMBER 3



PHOTO NUMBER 4

25 NOV 80  
TJT



PHOTO NUMBER 5

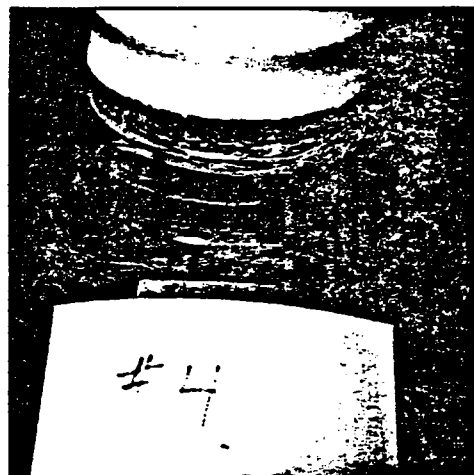


PHOTO NUMBER 6

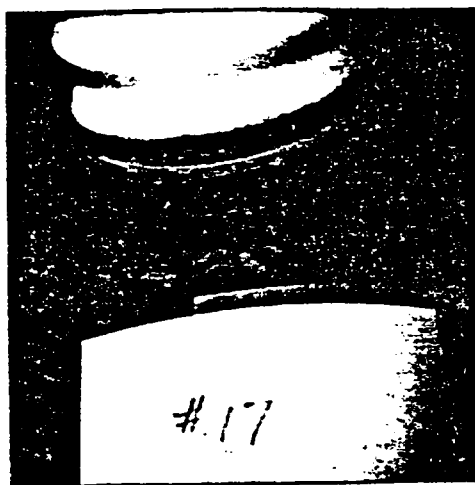


PHOTO NUMBER 7



PHOTO NUMBER 8



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TJT

It should be noted as shown in Photos 9 and 10 that the other 2 inductors which were not included in the random samples also failed. Therefore, actually the failure rate of the first 10 inductors tested is 8.

25 NOV 80  
TJT

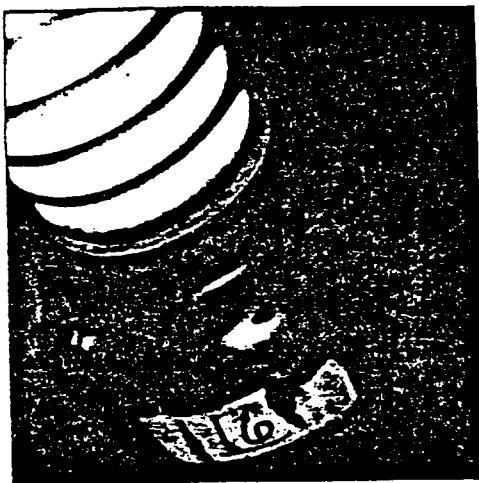


PHOTO NUMBER 9



PHOTO NUMBER 10

TJT 06 OCT 80

## TIGHTENED INSPECTION TEST PLANS

## LOT SIZE G GP. II

## FOR 1% ACCEPTABLE QUALITY LEVEL

		<u>SAMPLE SIZE</u>	<u>ACCEPT</u>	<u>REJECT</u>
Single Sample Plan Gp. G		80	1	2
Double Sample Plan Gp. G	First	50	0	2
	Second	50	0	2
Multiple Sampling Plan Gp. G	First	20	*	2
	Second	20	*	2
	Third	20	0	2

## FOR 4% ACCEPTABLE QUALITY LEVEL

		<u>SAMPLE SIZE</u>	<u>ACCEPT</u>	<u>REJECT</u>
Single		32	2	3
Double		20	0	3
		20	3	4
Multiple		8	*	2
		8	0	3

If we are willing to accept a 4% failure rate: (multiple sample test)  
 then Test 16 - crack none to accept.  
 Test 8 - crack two to reject.

If we are willing to accept a 1% failure rate: (multiple sample test)  
 then Test 60 - crack none to accept  
 Test 20 - crack two to reject.

\* Cannot accept at this testing level

TJT  
11-10-80  
Page 1

REPORT OF CONDITION OF CAPACITOR ISOLATORS ON ARRIVAL FROM U.I. -  
TAG NUMBER TO SERIAL NUMBER CROSS REFERENCE ARE INCLUDED

Tag #5	The first one is marked No. 5 - S/N 500176 -- No cracks. 1.80 mh
Tag #6	S/N 500143 -- No apparent major cracks. There is some superficial neck cracking, however, which doesn't extend more than 1/32 inch into the outer coating. 1.86 mh
Tag #2 Cracked on Arrival	S/N 500136 -- This is marked No. 2. There is 1/8 or 1/16 inch separation where the main body joins the taper to the neck. It appears to have been rubbed through by wear. Other miscellaneous nicks and scratches including a small nick in the porcelain. The wear through separation is apparently 3 to 4 inches long and 1/16 inch wide. T.90 mh  It appears that it is the joint between an upper cap and a lower body of some kind if I am not mistaken.
Tag #3	S/N 500180 -- It is marked with a tag marked 3. No visible cracking. 1.76 mh
Tag #4	S/N 500193 -- It is marked No. 4. No visible cracks.
Tag #15 Cracked on Arrival	S/N 500175 -- A crack that runs one-third around the body of the neck. Tag marked No. 15. 1.82 mh
Tag #16	S/N 500197 -- No visible cracks.
Tag #17	S/N 500169 -- Tag marked No. 17. There is a small visible worm hole in the lower side of the main body where one of the suspension straps was during the molding process that had been sanded off but left about 1/8 inch indentation. No cracks were extending from that area, so it appeared fairly thermally stable. 1.83 mh
Tag #18	S/N 500161 -- Tag marked No. 18. No visible cracks. 1.80 mh
Tag #19	S/N 500199 -- Tag marked No. 19. No visible cracks. 1.86 mh
Tag #7 Cracked on Arrival	S/N 500187 -- There is a crack in the neck of this unit which extends approximately half way around it. It is tagged No. 7. No main body cracks that I can see. 1.87 mh
Tag #8	S/N 500174 -- Tag No. 8. No visible cracks.

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Tag #9 S/N 500185 -- Tag No. 9. This isolator is cracked around the neck about  
Cracked 1.81 mh half way. I see no cracks in the main body of the isolator.  
on  
Arrival

Tag #10 S/N 500182 -- Tag No. 10. No visible cracks.  
1.82 mh

Tag #20 S/N 500170 -- There is a crack in the neck which extends approximately  
Cracked 1.81 mh three quarters of the way around the neck. No cracks in  
on main body and the porcelain.  
Arrival

Tag #11 S/N 500167 -- Tag No. 11. No visible cracks.

Tag #13 S/N 500181 -- Tag No. 13. Crack approximately three quarters of the  
Cracked 1.81 mh way around the neck. No noticeable body cracking.  
on  
Arrival

Tag #1 S/N 500165 -- Label Marked No. 1. There is a crack in the neck approximately  
Cracked 1.84 mh half way around. No other visible cracking.  
on  
Arrival

Tag #12 S/N 500164 -- Tag No. 12. No visible cracks.

Tag #14 S/N 500173 -- Tag No. 14. No visible cracks.

Leightner #1 2.17 mh

Leightner #2 1.78 mh

## VITA

Thomas James Talley was born 30 October, 1945, in Ft. Worth, Texas. His parents, Dr. & Mrs. Paul J. Talley were living at College Station, Texas, where Dr. Talley taught Botany and Plant Physiology at Texas A&M until 1947. He attended schools in several states prior to graduating from high school in Pine Bluff, Arkansas in 1963. Following one year at the University of Arkansas, he entered the United States Air Force and was trained in heavy ground radar systems maintenance. Upon completion of 1 year AC&W radar training at the top of his class, he was selected to remain as an instructor. Later he also became qualified in airborne radar and navigation aids maintenance.

Tom entered Texas A&M in July of 1968 and began a period of study which he completed in December of 1971 by earning the degree of Bachelor of Science, specializing in Electrical Engineering. He worked for Texas Electric Service Company, an electric utility, in several positions including distribution engineering, personnel, gas operations, and advertising. He returned to Texas A&M University in 1977 where he completed an M.S. degree in December 1979 and entered the Doctor of Engineering program. This master's work was subsequently recognized by the National Society of Professional Engineers as being one of the 10 Outstanding Engineering Achievements of 1981.

He is currently the Supervising Electrical Engineer in the Nuclear Engineering Group assigned to the Comanche Peak Steam Electric Station. His responsibilities include all electrical and computer systems required to satisfy Post-TMI requirements.